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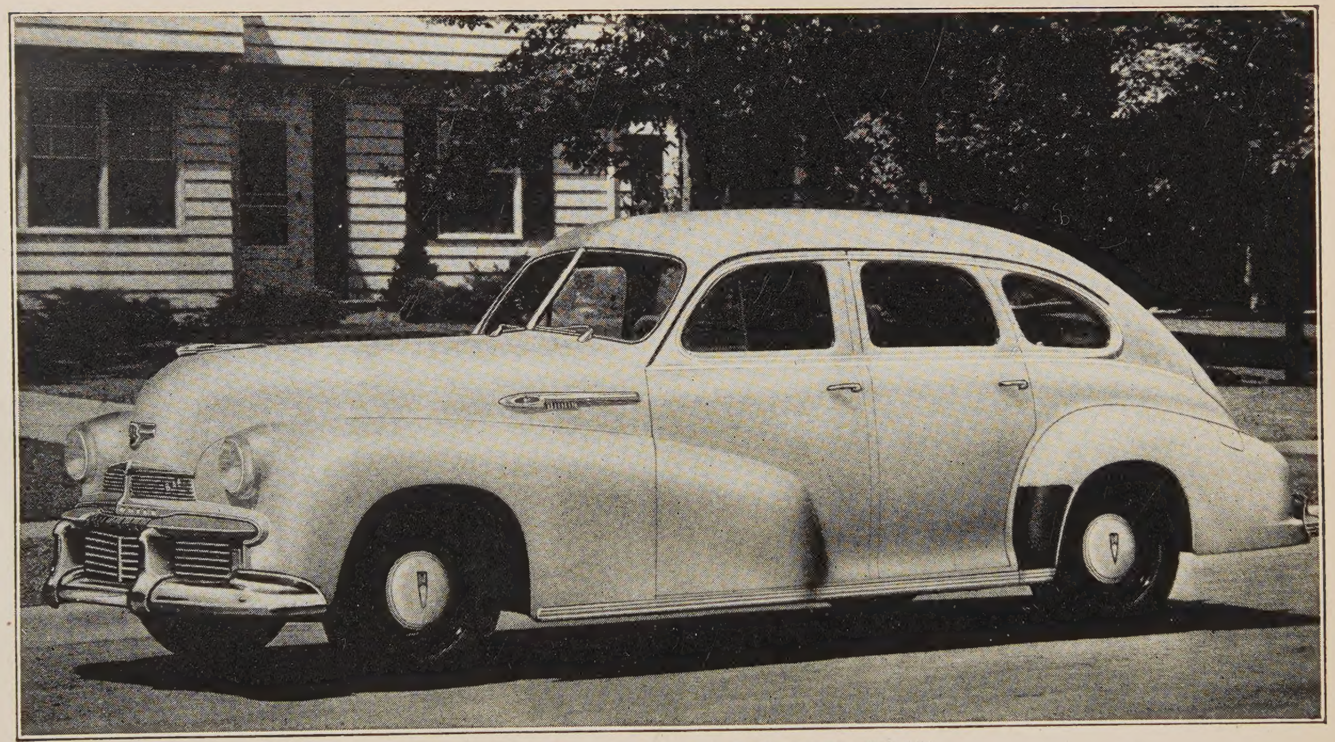

1942 OLDSMOBILE "70" SERIES FOUR-DOOR SEDAN
Courtesy of Olds Motor Works

AUTOMOBILE ENGINEERING

A HOME-STUDY COURSE AND GENERAL REFERENCE WORK

on the Construction, Care, and Repair
of Cars and Trucks; on Ignition and
Starting Systems; also Instructions on
Diesel Engines; Service Station Operation

Prepared by a Staff
of Automobile Experts
Under the Supervision of

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OVER FIFTEEN HUNDRED ILLUSTRATIONS • SIX VOLUMES

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FOREWORD

ALTHOUGH recorded history is not wholly agreed as to the first man in America to perfect and operate an automobile, this honor is generally accorded to Charles E. Duryea of Springfield, Massachusetts, who on September 12, 1892, operated a Duryea gasoline automobile in that city. By the year 1900, a number of "gasoline buggies" were in process of manufacture and by 1910 automobile building in the United States had begun to assume serious proportions. Quantity production methods have resulted in the building of over fifty-five million passenger cars and almost four million trucks.

Approximately, five hundred thousand persons are engaged in the production of automobiles, with a payroll of approximately seven hundred million dollars each year. The total number of jobs made possible by motor transport, which includes automobile manufacture, petroleum refining, sales and servicing, road construction, etc., is over six million each year.

Our highway systems total over nine hundred thousand miles of hard surfaced highways. Expenditures for highways in a recent year totaled approximately one billion dollars. Taxes paid by the automobile industry total almost one and one-half billion dollars yearly. Gasoline consumption is estimated at about twenty trillion gallons yearly and the consumption of automobile tires is in excess of fifty million. It is estimated that the vehicle miles traveled are more than one hundred fifty trillion yearly.

As a result of the highly developed skill of automobile production, the call for old-fashioned *repair service* is gradually being displaced by a call for a new type of man trained in *maintenance service.*

Perhaps the first line of defense, so to speak, against the needs of the modern motor car is the list of three hundred and twenty-five thousand gasoline service stations offering maintenance service in varying degrees. Next in point of number comes sixty-five thousand general repair garages and then some thirty-five thousand car dealers. The men required to man all of these stations require specialized training.

Specialized equipment has been developed, designed to help the garage men diagnose motor car troubles. It is a matter of record that the scientific equipment is more accurate than the human element and the up-to-date stations are requiring men who can handle this type of equipment.

There is no need to guess the type of lubricant required by any part of the automobile, nor is there any need to make an estimate or guess as to the exact amount of clearance to be allowed at any one point in the adjustment of the intricate automotive assemblage. Accurate information is provided in the way of lubrication charts, wiring diagrams and data sheets.

Service men have taken it upon themselves to attempt to make the automobile fool-proof and to make it a safer vehicle to go upon the highways. This has resulted in safety campaigns in the servicing of brakes, headlights, and the third vital item, front axle and steering geometry.

Although the principle of the Diesel or oil engine is practically as old as that of the gasoline engine, which has been developed on the Otto cycle principle, it was not until comparatively recent years that the Diesel has begun to find a very large place in the transportation field. Diesel engines have been speeded up and light weight Diesels are being rotated approximately as fast as heavier gasoline engines. The Diesel engines are finding their place in road tractors, road machinery, farm tractors, buses, and trucks. The auto-mechanic, who has a well-grounded understanding of the principles and practices common in the automotive field, has little difficulty to transplant himself into the Diesel engine service field. It is anticipated by many that further development of the Diesel will insure its place in the passenger car transportation field.

In the automobile racing field there have been a number of outstanding developments within recent years, chief of which is the propulsion of a motor vehicle over the salt beds of Utah at a speed in excess of three hundred miles per hour. Each year has seen the breaking of speedway records with higher and more efficient performances and records. There has been a tendency for road racing to come back into favor and this is being looked upon with special appreciation by some car manufacturers who are desirous of increasing the performance of their particular automobile. In this field the competition of foreign-made automobiles is being felt.

Considerable interest continues to be exhibited in the possibilities of a rear-engined power plant. More complete streamlining is always a matter of consideration by engineers. Fuel economy is receiving much consideration and is destined to play a part in engineering practice more and more. In the truck and tractor field for highway transportation of freight, there is a definite tendency toward the use of the pancake type of engine with the cab over it at the front of the vehicle. Outstanding examples of free design in engine placement are in placing engines behind the rear axle in buses and the use of the twin drive.

A great deal of the short haul business, which was handled at one time by the railroads, is now handled by trucks and tractor-trailers. The use of light-weight, high-speed, high-compression engines, similar to those utilized in the passenger car field, has become a general practice in highway freight service. This serves to prove the contention of automobile engineers that the automobile has a great deal more power than is really required for ordinary passenger car use. This fact has fostered the development of the house-type and display-type trailer coach drawn by passenger cars.

The last few years has seen a standardization taking place in the aviation field with the result that aviation industry is partaking more and more of the nature of a large public utility, such as a railroad or a steamship line. Young engineers interested in a life of service in this industry need to recognize this particular fact. The training required by these individuals is of an exceedingly high order. For every ship in the air there is a crew estimated at from five to ten men on the ground. It is in this field that many young automotive engineers are finding an outlet for their skills. It is now possible to travel into almost any part of the United States within twenty-four hours by means of regularly scheduled air-line service. It is also possible to travel into almost any part of the globe at exceedingly high rates of speed, using only the regularly established air-line service. More and more we are finding that mail, express, and freight are being handled by this service. Some of the most interesting and recent developments in the mining field, in the North American Continent and elsewhere, are being made possible through the use of the airplane for transportation of men and mining machinery into out-of-the-way places. While it is true that the development of light aircraft for personal use of the aviator has had more or less of a quiet season, impetus is being given to this development by certain work of the Civil Aeronautics Authority of the Federal Government.

Intimately tied up with all of the various phases of automotive progress in the field of transportation is the question of man-power. The automotive industry continues to afford to red-blooded American youths, who are willing and anxious to train themselves in the highly technical lines of service, one of the most popular and profitable fields of training and service. The young engineer, however, must realize that with all of the romance and interest in any phase of this great industry there comes also the need for scientific and exact application of knowledge and skill.

Table of Contents

Volume III

PAGE

Front Suspension—Front Axles—Steering Gears. *By Morris A. Hall. Revised by Ray F. Kuns*† *11

Independent Springing of Wheels. Knee-Action Wheels. Packard. Servicing Chrysler and Plymouth Independently-Sprung Front Wheels. Servicing the Chevrolet Knee-Action Front-Wheel Suspension. Studebaker Independent Front-Wheel Suspension. Front Axles: Chevrolet Truck and Passenger Car Through-Type Front Axle. Cadillac Steering Gear. Gemmer Steering Gears. Ross Cam and Lever Steering Gear. Ross Cam and Twin Lever Steering Gear. Saginaw Roller Bearing Steering Gear. Nash Ball Bearing Steering Column. Pitman Arm Stop. Shorter Pitman Arm. Steering Gear Troubles.

Springs and Shock Absorbers. . *By Morris A. Hall* . 95
Revised by Ray F. Kuns

Nash Balanced Ride. Semi-Elliptic. Hotchkiss Drive. Coil Springs. Independent Front-Wheel Suspension. Chevrolet Front-Wheel Suspension. Ford Center-Poise Springing. Hudson-Terraplane. Silent U-Shackle. Dodge. Shock Absorbers: Gabriel. Ford. Oldsmobile. Delco-Lovejoy-Buick. Sway Bars and Stabilizers. Ford "V-8" Springs.

Wheels. *By Morris A. Hall. Revised by Ray F. Kuns* . . . 133

Passenger Car Wheels: Wood Wheels. Wire Wheels. Welded Steel Spoke Wheels. Disk Wheels. Bus Wheels. Truck Wheels. Cast-Steel Wheels. Miscellaneous Wheel Types. Servicing Hints on Wheels. Balancing Automobile Wheels.

Tires. *By Morris A. Hall. Revised by Ray F. Kuns* . . . 147

Tubes. Plies. Cables. Treads. Types. Tire Loads. Wheel Alignment. Valves. Rims. Dual. Hints for Mounting and Dismounting. Inner Tube Repairs. Inspecting, Repairing and Vulcanizing Balloon Tires. Goodyear Criss-Cross Method of Balloon Tire Repair. U. S. Method of Repairing Low-Pressure Tires. Camel-Back for Retreading. Full Circle Retreading.

Brakes . . . . *By Ray F. Kuns* . . 203

Braking Systems Theory. Mechanical Brake System. Lincoln-Zeyphr. Hydraulic Brake System. Servo Action. Brake Drums. Brake Shoe. Air Brakes—Operation and Service. Vacuum Brakes. Brake Service. Trouble Shooting Chart. Brake Testing and Brake-Testing Equipment. Brake Relining. Reconditioning Brake Drums. Brake-Drum Lathes. B.K. Vacuum Power Brakes. Vacuum Operated Trailer Coach Brakes. Bendix-Westinghouse. Warner Electric Trailer Brake. Chevrolet. Servicing Lockheed Hydraulic Brakes. Wheel Brake Units. Hydraulic Brake Service and Maintenance Chart. Bendix Duo-Servo Brakes. Trouble Shooting on Bendix Duo-Servo Brakes. Servicing Midland Steeldraulic T-Section Brakes. Servicing Chevrolet Huck Type Brakes. Servicing Standard Model 1934 Chevrolet Brakes. Ford "V-8" Brakes. Transmission Brakes. Bendix Duo-Servo-Hudson-Terraplane. Buick. Studebaker.

Diesels for Transportation . . . *By K. C. Smith*
and Ray F. Kuns . . 311

Four-Stroke Cycle. Two-Stroke Cycle. Single-Acting. Double-Acting. Hercules. "DHX" Four-Stroke.

High-Speed Diesel Engines . . *By L. H. Morrison* . . 339

Fuel-Ignition Systems. Fuel for High-Speed Engines. Cummins Diesel. Fairbanks-Morse High-Speed Diesel. Winton Diesel.

Trucks . . . . *By F. R. DeForest* . . 404

Mechanical Details: Engines. Valves. Valve Springs. Valve Clearance. Valve Timing. Lubrication System. Cooling System. Air Cleaners. Truck Clutches. Transmissions. Rear Axles. Brakes. Service Information. Selecting a Truck.

Index 449

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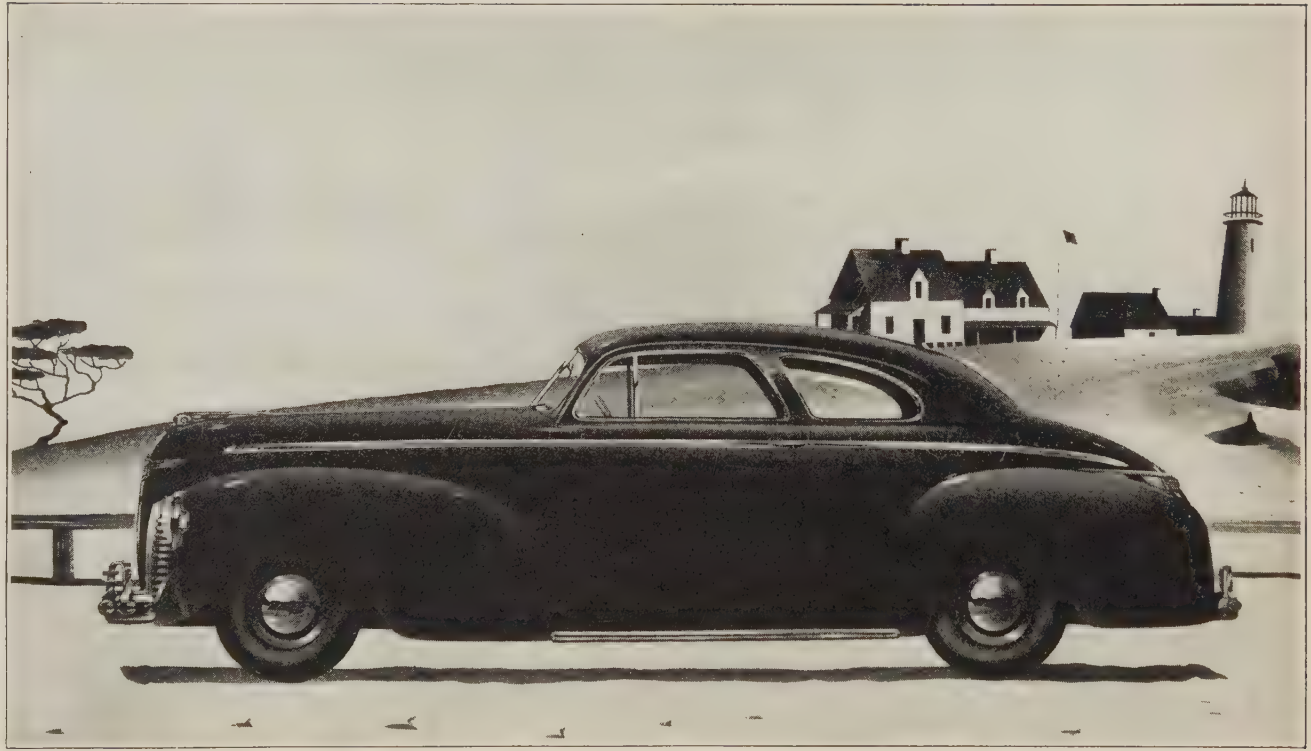
*For page numbers, see foot of pages.

†For professional standing of authors, see list of Authors and Collaborators at front of volume.



DODGE 1941 TWO-DOOR COUPE

Courtesy of the Chrysler Corporation

FRONT SUSPENSION—FRONT AXLES—STEERING GEARS

PART I

Steering of the automobile is accomplished not alone through the action of the steering gear, but through the front axle in the case of older cars, and through the front suspension in the case of newer designs. The features of design of the suspension units and the steering gear, are so closely interrelated that it is best to consider them in relation with one another. Steering and axle geometry are the same, whether through axle or independent suspension is used. Service of steering gears and front suspension may be performed in a satisfactory manner, if the service man understands the underlying principles. These principles are described in Parts 1, 2, and 3 of this volume. Concrete cases of the application of the theories are also given.

INDEPENDENT SPRINGING OF WHEELS

The advent of independent springing of automobile wheels in America, is likely to follow along after somewhat the same general lines which have been developed for this work in Europe. Certain principles of spring and axle action are fundamental considerations when studying independent springing design.

What happens with a conventional, through axle when an obstacle on the road is encountered, is shown in Fig. 1. Notice the direction of movement, as indicated by the arrow, is in an arc. Note also that as the wheel and axle move upward, as shown by the dotted line, the wheel comes out of its original vertical position. Engineers claim it is desirable to offset this action, as shown in Fig. 2, where it will be noted that the front wheel is carried on a spindle body which has its movement controlled by means of two radius arms. The direction of movement, as indicated by the arrow, shows a vertical movement, although the foreshortening of the arms pulls the wheel inward somewhat.

Some of the advantages claimed for independent springing are lighter unsprung weight, higher cruising speed, more comfortable riding, better steering since the action of one front wheel does not affect the action of the other, and similar advantages. The tendency of a car to roll when rounding a turn is more pronounced with independent springing devices than with the conventional springing devices, although recent developments in Europe have shown that this tendency may be overcome.

Possibly the more commonly used forms of independent springing for wheels are shown best in Figs. 2, 3, and 4, which show, respectively, the use of double radius arms, the use of a half axle, and the use of double crank arms. Other forms of suspension are the use of the single radius arm, such as is used in connection with the rear axle of the Crossley car. Another form of suspension is that shown in Fig. 5, which shows the use of two quarter-elliptic springs over and two radius arms under the drive shaft of a front drive automobile. This same device may be used for either front or rear drive and four quarter-elliptic springs may be used as well as two quarter-elliptic and the two lower radius rods.

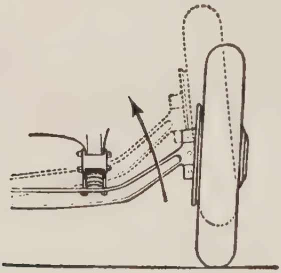


Fig. 1. Conventional Springing

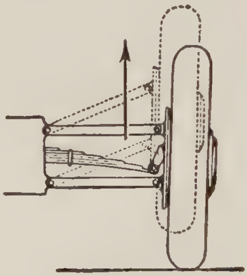


Fig. 2. Independent Springing

The design shown in Fig. 3 is termed a half-axle design, this one being controlled by coil springs. It is the principle used on the Mercedes Benz. While this allows the rear wheels to splay or spread apart with the roadway under load, and come together when the load is relieved, it is claimed that the

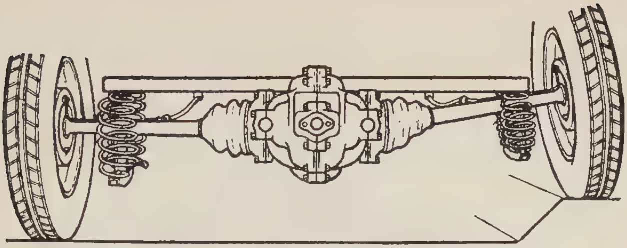


Fig. 3. Half Axle Independent Springing

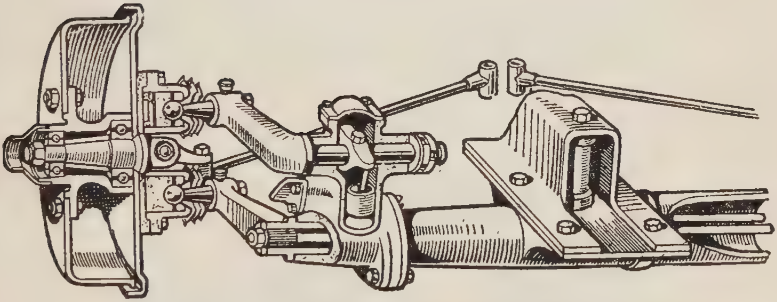


Fig. 4. Double Crank Independent Springing

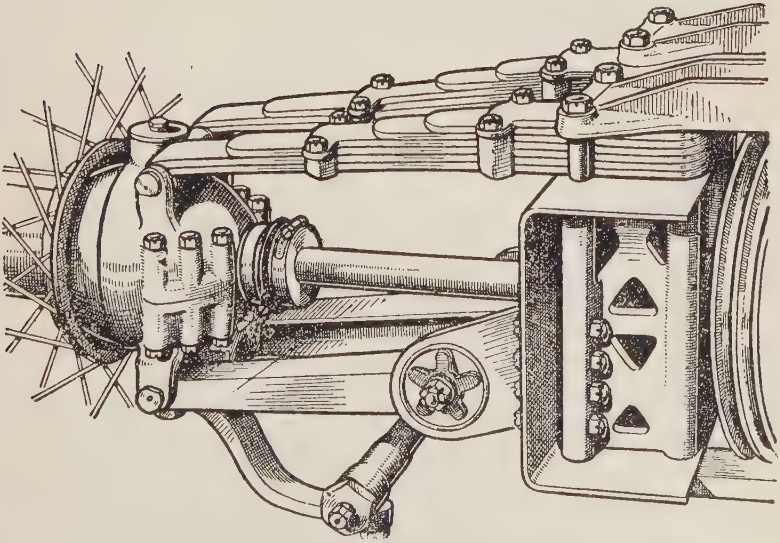


Fig. 5. Double Cantilever and Radius Arm Independent Springing

forward motion of the wheels, together with this peculiar swinging axle motion has the effect of damping out undesirable spring action. This would be due of course to the tendency of the tires to slip (scrape sidewise) in or out on the roadway as the tread was changed under load. If properly designed, the amount of scuffing is not unduly high.

When the radius arms are applied to the front wheels, they of course must be so designed as to transmit the forward thrust necessary to propel the wheels with the chassis. Accordingly these are usually found to be in angular form, wider at the base than at the outer ends. Sometimes this design is applied to both lower and upper radius arms and again only to one, as is shown in the case of the Sizaire system. This appears in Fig. 6.

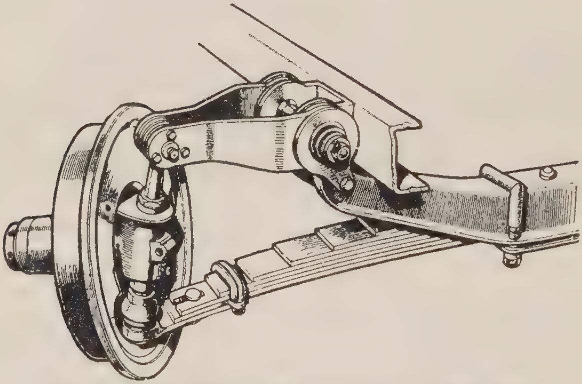


Fig. 6. Single Radius Arm and Cantilever Independent Springing

The crank type of spring suspension is illustrated in Fig. 4. In the case of this design, used on the Mathis, two cranks are used in order to maintain the spindle body in proper alignment when resisting brake torque. In some instances where crank type suspension is used, either coil or leaf springs are used in conjunction with them. In the case of the Mathis, the hollow tube or cross housing is used, the forward end of the lower crank arm being rigidly attached to the outer end of a torque or torsion bar carried within the tube. The inner end of this bar is anchored against turning or rotating and the twist within the torsion bar resists the weight of the load and produces springing claimed to be desirable. In the case of the Mathis, the upper crank arm is attached to a hydraulic piston which serves as a shock absorber.

Another type of independent springing is the one of a cylinder and piston-like arrangement for the steering knuckle mounting, that is, the position ordinarily occupied by the king bolt or spindle body bolt is constructed in the form of a piston, this being fitted within a vertical or slightly inclined cylinder. On striking an obstruction, the piston is made to move within the cylinder, movement being controlled usually by some form of coil spring. The chief objection to this type seems to have been the rapid wear occasioned between the piston and cylinder.

KNEE-ACTION WHEELS

While independent springing of front wheels had been a rather common thing in the European field, it was only in 1934 that such designs found ready application to automobiles in America. Back of these designs and their application to American cars are months and months of experimental work. Two of America's great corporations, General Motors and Chrysler Motors, adopted units for their front wheel suspension which are quite similar. In fact, both are after the same general design.

In America to date, nothing has been done with the independent springing of the rear wheels; however, it is claimed that by springing the front wheels independently a very much better ride is secured for the automobile. This is due primarily to the fact that what is termed a "soft spring" may be utilized for the front wheels. Pitching, which was so common with the conventional semi-elliptic spring for the front end of the automobile, is claimed to be almost wholly eliminated due to the fact that the soft springs at the front permit the frame of the car to proceed on an even keel although one wheel may have bumped into a depression or passed over an obstruction. Since the frame of the automobile is maintained on an even keel, the motion to the frame occasioned by the rear wheels

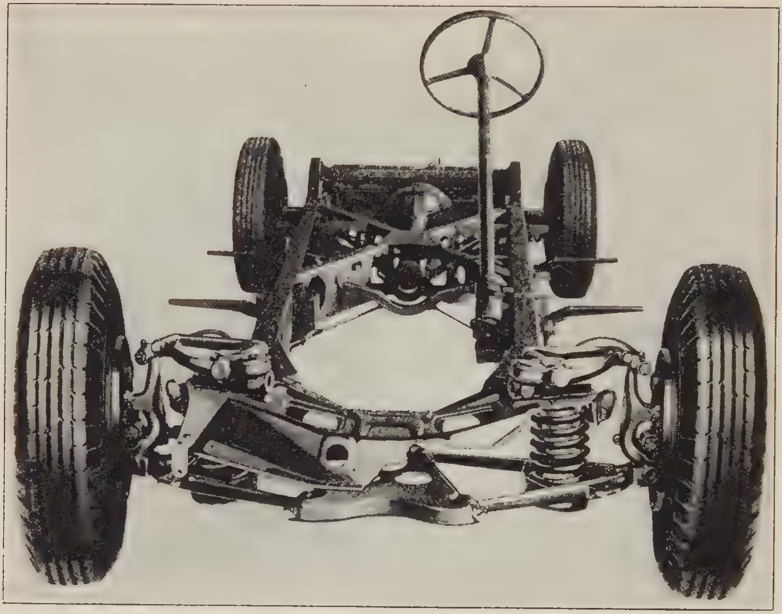


Fig. 7. Buick Chassis with Independent Knee-Action Wheel Suspension

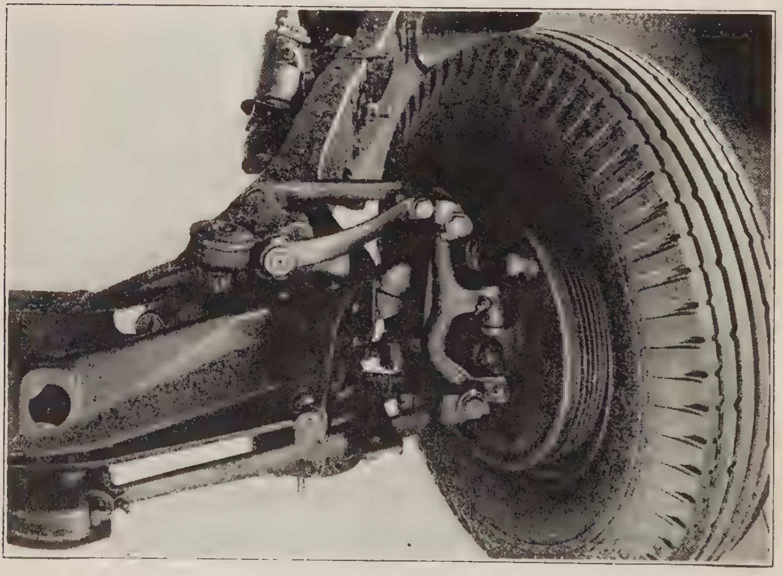


Fig. 8. Individual Springing of the Left Front Wheel on 1934 Buick

passing through the same depression or over the same obstruction does not have such a serious effect upon the automobile, as is the case when the front end of the frame is descending just as the rear end is pitched upward by the rear spring.

Buick Chassis. The Buick chassis, Fig. 7, is shown with a very heavy frame, the front end of which has been widened out in order to receive the new type of spring suspension. The right-hand side of the suspension is in full view, while the left-hand side has been cut away to show some of the details. It will be noted here that there are two V-type or wishbone type of arms, the lower one somewhat longer than the upper. The upper arm incorporates the shock absorber while the lower arm supports the bottom of the coil spring. Note that both of these arms are in turn attached to the vertical yoke in which the wheel spindle body is fastened by means of the usual king pin. This is shown more clearly in the individual springing of the left front wheel of the Buick, Fig. 8, the left wheel being cut around sharply to show the parts. It will be noted that a jack pad has been incorporated with the lower arm, this being immediately in front of the spring saddle. Note also that the car frame has been thrown outward at this point so that the wheel actually pivots around it. The king bolt and radius arm construction are conventional.

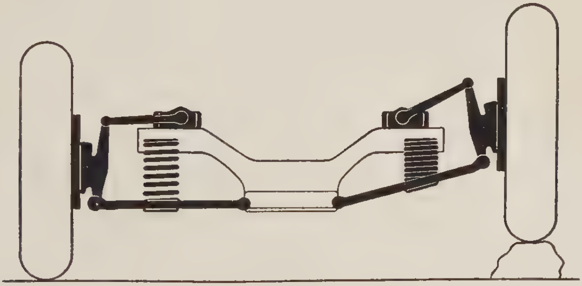


Fig. 9. Graphic Illustration Showing Geometry of Knee-Action Front Wheel Suspension

Spring Wheel Operation. The plan of the independently sprung wheel design is shown in graphic form in Fig. 9. On the one side the spring is normally loaded and the parallel arms stand in horizontal position. The other side is shown as passing over an obstruction in the road which has caused the spring to be compressed. As this happens, it will be noted that the long bottom arm is thrown outward more than the short upper arm. Thus while the lower arm tends to bring the wheel, hub, and spindle body inwardly toward the frame, the short upper arm tends to bring the upper end of the yoke in more rapidly than does the lower one so that the respective distances (track) between the centers of the tires when in a normal position and when passing over an obstruction remain the same or practically so, thus reducing the amount of tire scuffing which would otherwise be occasioned.

Spring Carries Load Only. Contrary to the functions of the usual leaf-type spring—which has among other duties those of propelling the front axle, keeping it in alignment with the car frame, maintaining the front axle geometry, and carrying the car load—the new type coil spring has only the car load to carry. Propelling the wheel forward, keeping the wheel in proper geometrical alignment, taking all side thrust, and, in fact, every duty outside of actual weight bearing is performed by the V-type parallel arms. These parallel arms or wishbone units are given a peculiar form at the center of the car frame where it will be noted that the rear member of the wishbone is constructed somewhat longer than the forward member of it. The same design is maintained in both the General Motors and the Chrysler product.

Rolling on Turns. With the type of construction illustrated for the Buick and Plymouth independent springing of front wheels there is a tendency for the car to roll on turns, this being the chief drawback to this type of design. For instance, when proceeding around a turn at cruising speed, the upper portions of the tires and wheels are inclined to be thrown outward, that is, to lean outward on the turn. In order to compensate for this, the Buick automobiles and certain others are equipped with a torsional stabilizer, which is shown in Fig. 10, at the rear of the automobile just over the rear axle. This device is a simple spring steel bar mounted in plain bearings to the frame side members. To this, simple steel bar crank arms are rigidly attached, so they will not turn on it. The lower ends of these arms, in turn, are attached by means of other and shorter arms to the rear axle housing near the spring saddle point. When there is a tendency for one side of the car to rise faster than the other, as would be the case in rounding a turn or striking a severe obstruction in the road, the tendency of one arm to shorten faster than the other sets up a twisting or turning movement in the steel bar held rigidly between the long upper arm. The resistance of this steel bar to such twisting has a stabilizing effect upon the car frame level and maintains it on an even keel.

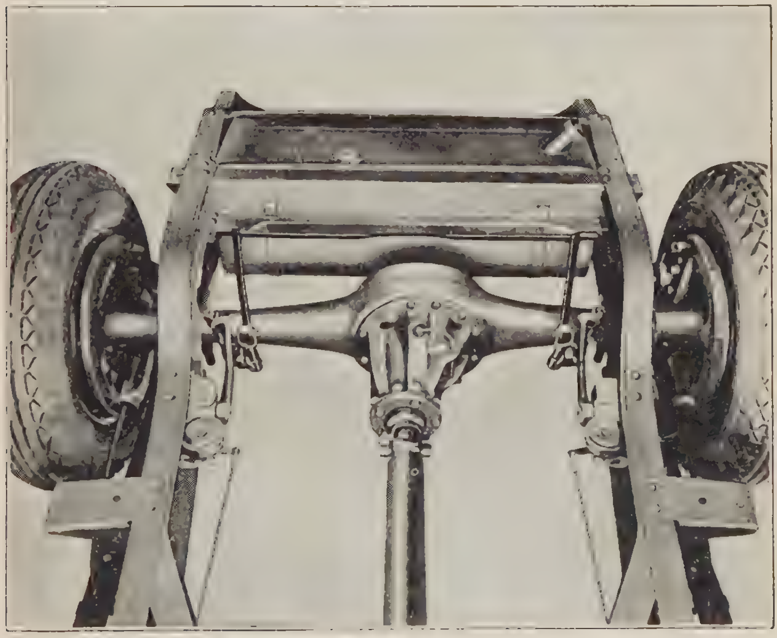


Fig. 10. Ride Stabilizer Designed to Control Body Roll

Steering Arrangement. With the new type of spring suspension, it has been found necessary to make quite a few changes in the steering arrangement so that now instead of having one through drag link, there are two short drag links, these in turn being connected at a central point just under the engine bed to an arm. In the case of the General Motors products, this is a bell crank arm; while in the case of the Chrysler Motors product, this is a simple lever. In the latter case, the Dodge, Chrysler, and Plymouth make use of cross steering so that a bell crank arm is not required.

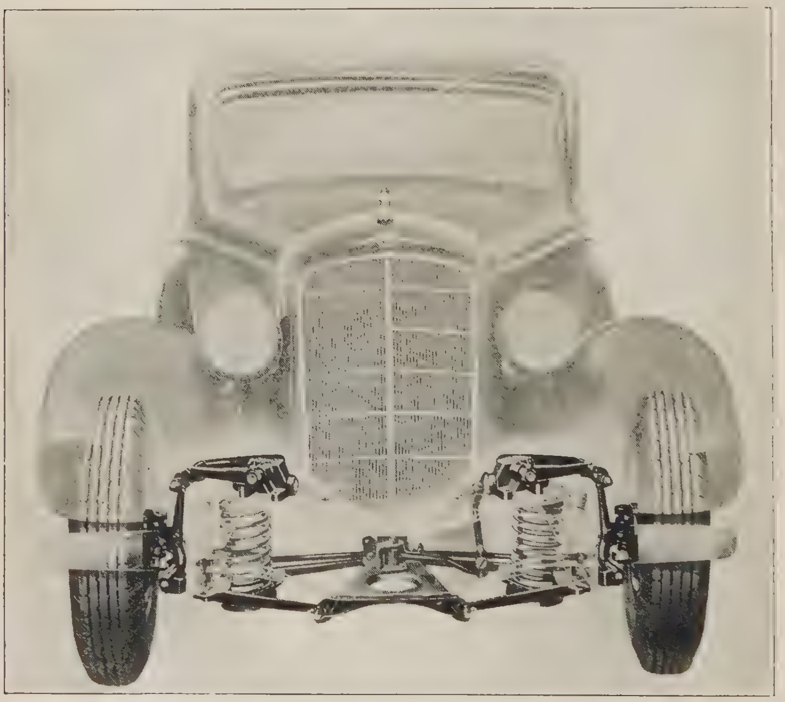


Fig. 11. Oldsmobile Independent Front Wheel Suspension

The General Motors cars, as in the case of the Oldsmobile shown in Fig. 11, make use of the conventional type of steering drag link suspension so that the bell crank is necessary. This construction is shown in Fig. 12, where the bottom view of the Buick installation is illustrated. Note the two short tie rods. A very good point to this arrangement is the fact that as the one wheel rises or falls on the independent springing,

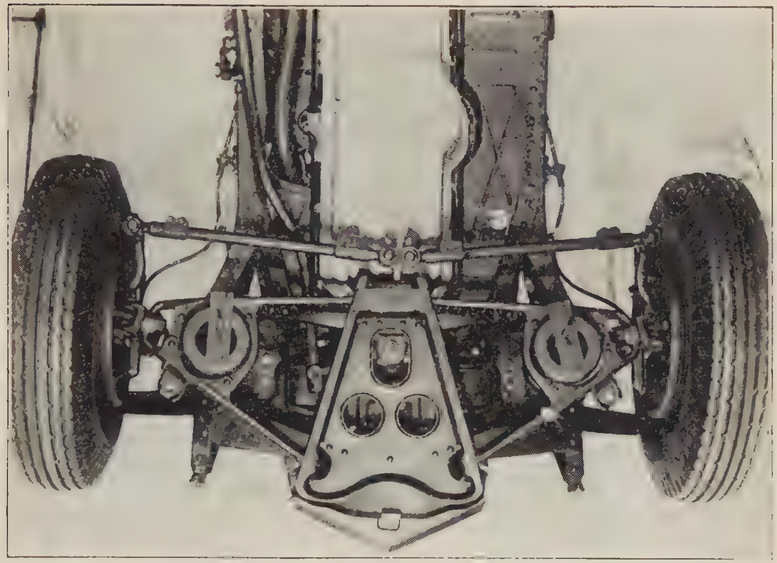


Fig. 12. Buick Front Wheel Suspension and Frame Structure Viewed from Below

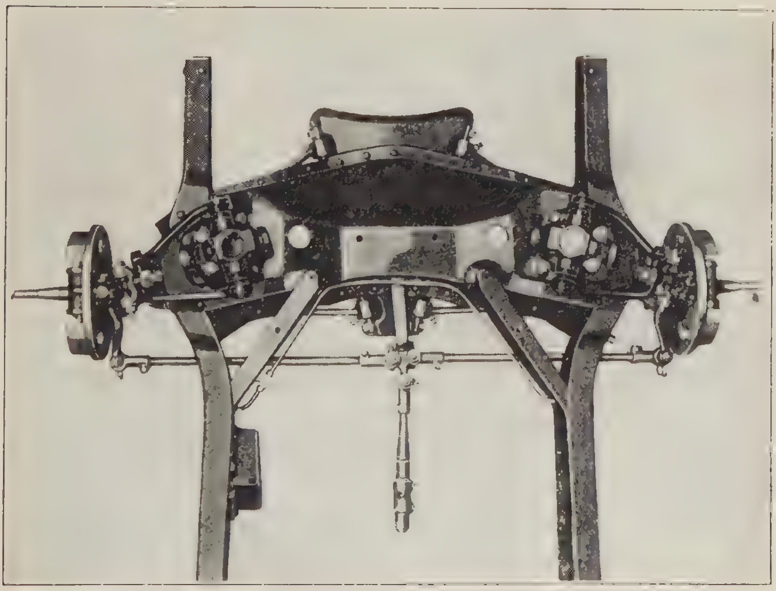


Fig. 13. Plymouth Frame and Front Wheel Suspension Viewed from Above Showing Shock Absorbers with Wishbone Arm

the outer end of the tie rod moves very much in the same arc with the one side or one half of the tie rod moving about a similar arc. In other words, there are three arcs described at each wheel movement upward or downward, one of these being described by the lower wishbone, one by the upper shock absorber wishbone and one by the half tie rod on that side of the structure. Inasmuch as these are all practically in the same plane, it will be found that there is no tendency to disturb the direction of travel of the wheel, thus eliminating the setting up of shimmy and tramp.

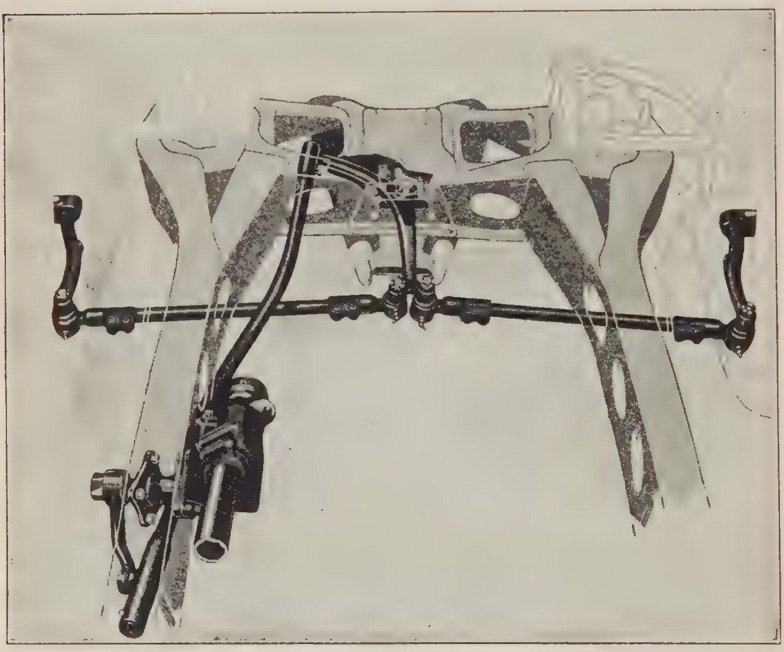


Fig. 14. Buick 1934 Double Tie Rod and Bell Crank Steering System

The Plymouth frame and front wheel suspension, featuring shock absorbers with wishbone arm, is shown in Fig. 13.

Along with the development of this new device, there has been a further refinement in the steering gear, which has been increased in efficiency and gear ratio, frictionless bearings being used to a much larger degree than heretofore.

The layout of the Buick drag link and tie rods arrangement is shown in Fig. 14. Note that a fore or aft motion of the drag link is imparted by the usual steering wheel motion which causes the bell crank, mounted at the center of the heavy forward cross member, to move, thus throwing the rearmost end of this bell crank to the right or left and effecting the steering. Both of the tie rods are adjustable so that the toe-in of each wheel is affected or secured independent of the other.

Special Tires Required. An entirely new tire with a special tread pattern has been designed in order to assure just as long life with the new type of spring suspension as was possible with the old. Incidentally, of course, it was of interest to the manufacturer to have larger tire cross sections, accordingly most tire sizes have been increased about one inch in cross diameter. The Buick tire pressures required are 21 to 25 pounds with 3 pounds higher when the tire is hot. The new tread design has had the corners rounded off so that the tires really are more nearly round where they contact the road surface. Side wall ribbing now runs in a radial rather than an angular direction. The side wall construction of the new tire has had the fabric layers run differently. With these new designs it has been found that tire wear is rather uniform and squealing or other road noises have been eliminated. The life of the tires is claimed to be quite satisfactory.

Servicing the New Spring Suspension. The new spring suspension involves lubrication of almost twice as many points as was formerly the case. The most important point in the service of new spring suspension units is to have the proper grade of lubrication applied at the proper intervals of time. If this is neglected, wear will occur in the yokes and bushings so that misalignment of the parts will occur and result in difficult steering or other trouble. Whenever any servicing of the front wheel unit or the steering gear is to be done, it is very essential to remember that the suspension is very sensitive to an unusual amount of friction or again to any undue looseness in the front end joints and elements. The friction within the steering gear units must be minimized to the lowest possible degree. Backlash in the steering gear should be removed and the units must be maintained free of backlash in service.

Shock Absorbers. It will be realized, of course, that the duty of the shock absorber is a very much more positive and definite one than ever before. Not only does this unit serve to keep the front wheels properly aligned, but it also serves to check both upward and downward motion of the wheel spindle. Buick automobiles make use of the inertia type of shock absorber, at the forward end and double-acting (without the inertia control) for the rear end. The front end shock absorber calibration is very finely calculated and quite sensitive. It is absolutely imperative that no dirt be allowed within the shock absorber and that the oil used be of the proper consistency and further that the proper level of the oil be maintained.

Caster Angle. When the cars are assembled at the factory, they are adjusted to a predetermined caster angle. Unless this has been disturbed or it becomes necessary to change it owing to an accident, the caster angle ordinarily would require no changing in the life of the automobile. If it is necessary to change it, there is a simple device incorporated for the purpose.

Chevrolet and Pontiac Front Wheel Suspension. This is what is known as the Dubonnet principle whereby each front wheel is attached to the end of a swinging crank arm. This arm is not shown in Fig. 15, which shows the 1934 Pontiac wheel suspension cutaway to illustrate the spring and shock absorber construction. It will be noted that the front end of the frame has a very heavy cross member built into it. At the end of this cross member there is a yoke provided and in this yoke is mounted the rear end of the suspension unit, it being secured thereto by means of the usual king pin or bolt construction. The reader will remember that the new spring suspension is steered with the wheels, the wheels and the entire unit being swung side to side as steering is effected. It will also be noted that inasmuch as the steering gear is mounted directly on the car frame and these units are mounted onto the same car frame, the action of the wheels as they pass over irregularities on the road has no effect upon the drag link position. This is claimed to make for very sure steering of the unit.

There are two heavy springs within the oil type chamber of the unit; these also serve to carry the shock absorber unit at the forward end. The crank arm which carries the wheel spindle on its rear end is pivoted at the forward end as shown just at the cam mounting position of the unit. As the wheel action causes the wheel spindles to move upward and downward, a rocking motion is imparted to the cam mounted on the stub shaft carrying the forward end of the crank arm. This rocking motion controls the spring and wheel action, one half of the shock absorber acting on deflection and the other

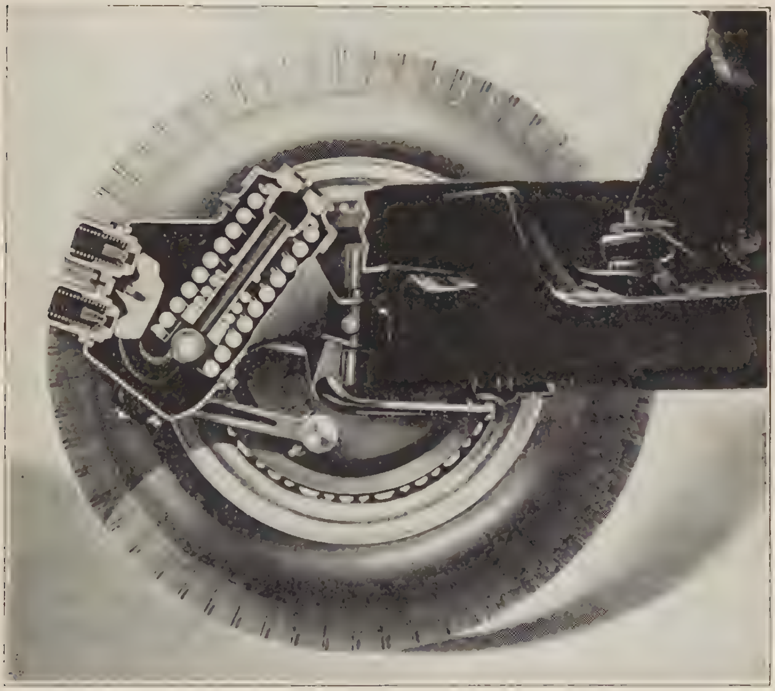


Fig. 15. Pontiac and Chevrolet Independent Suspension Front Wheel Unit

half on rebound. Continuing from the cam rearward is noted a short arm which, by means of a needle bearing, supports on its end a cup which rests on the bottom of the heavier of the two springs. It will be seen that a slight motion at this point will take care of considerable motion at the wheel spindle point.

Contained within the larger spring, which is used to carry all the usual load, is a small spring, which is used to receive heavy shock and thus prevent the large spring from bottoming. This smaller inner spring will absorb heavy loads in a very short movement.

The brake flange and the anchor plates are freely mounted on the wheel spindle and the correct geometrical relation between the spring unit and the brake mechanism is maintained by means of a radius rod anchoring to the bottom of the housing. This arm should not be confused with the crank arm which carries the wheel spindle inasmuch as that one is almost completely hidden in the illustration.

It will be noted that a tubular guide is secured to the collar and extends upwardly and is received in a spherical headed sleeve against whose upper flange the outward spring thrust is taken and whose lower flange engages with the inner spring when it comes into action. It will also be noted that there is a threaded cap provided with a central spherical seat which takes the thrust of the sleeve head and permits the necessary oscillation of the sleeve guide unit. This threaded cap permits adjustment to compensate for variations which affect the car height. The larger of the two springs provides the unit deflection at the wheel of approximately 115 pounds per inch through a range of 3⅝ inches of wheel travel below normal to approximately 2 inches above normal. The remainder of the wheel travel range, which is approximately 1 inch upward, is controlled by means of the inner spring which comes into action and builds up a pressure at the wheel at the rate of approximately 540 pounds per inch. Lubrication of the Chevrolet-Pontiac unit is through the shock absorber oil, and it is very important that this be maintained at the proper level. Note that on the upper outward surface of the unit a small plug is provided. The oil level should be maintained to this point.

PACKARD FRONT WHEEL SUSPENSION

The front wheel suspension is of the independent type, and is composed of two horizontal lever assemblies, a vertical wheel support member, and a helical spring, a steering knuckle assembly of the reverse Elliott type and the usual brake support plates attached to the steering knuckles.

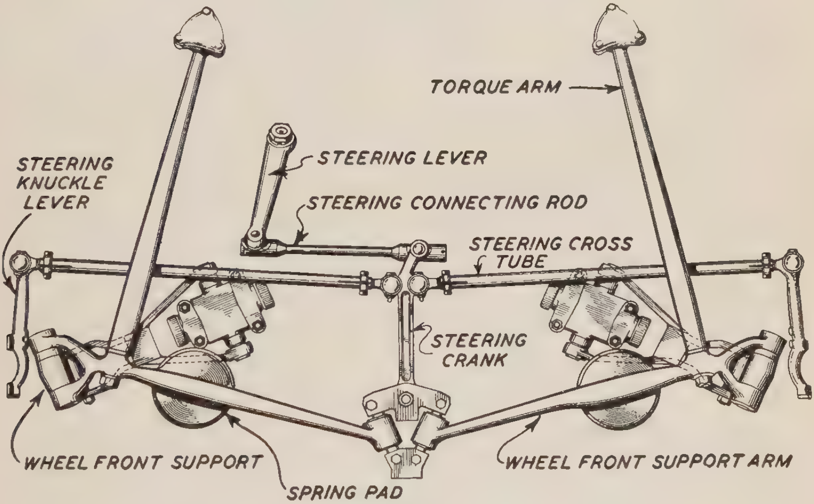


Fig. 16. Packard Front Wheel Suspension
Courtesy of Packard Motor Car Company, Detroit, Michigan

The support and torque arm assembly or lower arm, consists of two arms, the front or supporting arm and the rear or torque arm, as shown in Fig. 16. The support arm, which is a heavy steel forging, has an integral pad on which the suspension coil spring rests. The support arm is attached to the reinforced front cross member at its inner end with a rubber bushing.

The torque arm, which is constructed of tubes of steel, is bolted rigidly to the support arm close to the wheel, and at the other end to the box-shaped section side rail at a point of attachment close to the dash in a round shaped rubber bearing.

These points of attachment are the axes about which the lower lever moves or oscillates, and the distance between these points is very important in keeping the wheels in proper alignment. With such distance between the located centers of supports, wheel misalignment is kept down to a very slight amount.

The strength of the parts used, and the construction of the entire wheel suspension, have given ample strength to withstand the braking load, and allow for proper caster angle. The entire braking load is taken by the torque arm, which, because of its husky construction, actually allows a larger braking effort on the front wheels than would be permissible without it.

The king-pin caster angle is permanently fixed by the torque arm, and because of the length of the torque arm, very small variations in the caster angle are likely to occur, consequently, no means of adjustment is needed or allowed for.

The torque lever consists of double steel arms welded together to form a single, rigid unit. This single, rigid unit insures the proper camber angle, takes the thrust load, operates the shock absorbers and limits rebound. Bushings are located in the elongated holes in the outer end of the lever. These bushings are changed, if necessary, to obtain the correct camber angle when the cars are assembled at the factory, and it should not be at all necessary to change them while in service.

SERVICING CHRYSLER AND PLYMOUTH INDEPENDENTLY-SPRUNG FRONT WHEELS

The front wheels are individually suspended on steering knuckles and are fixed by knuckle supports which are connected with the upper and lower control arms (Fig. 13). Coil springs are placed between the lower control arms and the frame side rails. Vertical wheel motion is damped by double-acting hydraulic shock absorbers attached to the upper ends of the knuckle supports through the shock-absorber arms. Two steering-knuckle tie rods are employed to connect the front wheels. Self-adjusting ball joints are used at the points where they attach to the steering-knuckle arms and the intermediate steering arm.

Lubrication. The following parts should be lubricated with semi-fluid chassis lubricant, through the pressure nipples, every 1,000 miles: steering knuckles, upper and lower knuckle support bushings, lower control-arm bushings, tie-rod ball joints, intermediate steering arm bearings, drag link ball joints. Cars operated principally on gravel or dusty roads may need to be lubricated more often, and should be serviced as required.

Adjustments. Adjustments are provided for caster, camber, and toe-in, but if any of these angles become upset through accident, do not attempt to make any adjustments until the bent or damaged parts have been replaced. Correct alignment of front wheels must be maintained to assure continuous easy steering and maximum tire mileage. The wheel bearings should be properly adjusted. The tires should be inflated to specifications, before checking or making any adjustments. Measurements should be made with the car setting on a level floor, and front wheels must rest on floating turntables when checking caster and camber, to obtain a true reading.

Steering Angles. The caster angle should be $\frac{1}{2}$ to $2\frac{1}{2}$ degrees ($1\frac{1}{2}°$ preferred); the camber angle, $\frac{1}{4}$ to 1 degree ($\frac{1}{2}°$ preferred); the pivot or king-pin angle, $8\frac{3}{4}$ to $10\frac{1}{4}$ degrees, depending on the camber angle; king-pin angle plus camber angle, 10 degrees (plus or minus $\frac{1}{2}$ degree); the toe-in, 0 to $\frac{1}{8}$ inch; excessive toe-in is measured on a wee-gee board or similar wheel-aligning equipment, or $\frac{1}{16}$ inch to $\frac{1}{8}$ inch as actually measured at the hub height on the wheel felloe. The turning angle is 33 degrees toward the rear. Unless the front wheels are resting on floating turntables, an inaccurate reading is bound to be the result.

To Adjust Toe-in. Adjustments for toe-in must be made on both tie rods. Set the front wheels in exact straight-ahead position with the steering gear at mid-position and with the intermediate steering arm approximately parallel to the center line of the car. Next loosen the clamp bolts on both ends of each tie rod (Fig. 18). Turn both tie rods equal amounts, as required, to adjust the toe-in. Be sure to tighten the clamp bolts after completing adjustments.

After adjusting the toe-in, the length of both tie rods should be measured to determine if they are of equal length. Measurements are made from the threaded ends of the rods and *C* must measure the same length as *D* (Fig. 18). If tie-rod lengths are unequal, toe-in will be incorrect. The tie rods will have to be readjusted so they are both the same length, and toe-in is within the limits specified. Check the steering-knuckle arms to determine whether they are bent, if the tie rods cannot be made of equal lengths for correct toe-in. The arms, Fig. 19, should measure equal distances from wheel spokes (within $\frac{1}{8}$ inch) as measured with a steel square.

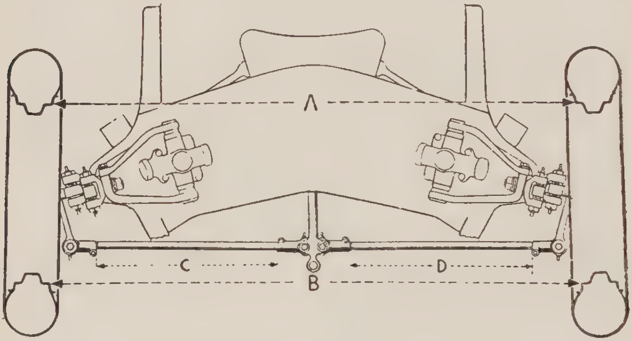


Fig. 18. Front-wheel Toe-in Adjustment

To Adjust Caster. Jack up the car so the weight is on the spring but not on the wheel. The jack should be placed, preferably under the jack pad on the lower control arm, next to the coil-spring retainer. Using a special box socket wrench with an offset handle, loosen the upper and lower control-arm yoke nuts which fasten the yokes to the lower control arms at the bottom and to the shock-absorber arms at the top. Tap the yokes with a rawhide or lead hammer, so they will be free to rotate. This will eliminate binding the yoke bushings. Remove the screw-type lubricant nipple in one end of the upper yoke center bolt. Loosen the clamp bolts on the arm of the upper yoke and on the upper end of the knuckle support. Insert the hexagon caster adjusting wrench through the lubricant nipple hole, and turn the yoke center bolt to move the upper end of the knuckle support; back, to increase caster, and forward to decrease caster, as required.

Tighten the clamp screws, reinstall the lubricant nipple and tighten both yoke nuts. Remove the car from the jack, and check caster. If the caster does not check within the specified limits, repeat the operations.

Note. Whenever adjustments are made to change the caster angle, the camber angle also changes. Therefore, always check camber and adjust if necessary after resetting caster.

To Adjust Camber. The camber angle, which is the amount the front wheels incline outward at the top, is adjustable. It can only be changed by the addition or removal of spacers between the steering-knuckle upper control arm yoke and the control (shock absorber) arm. Adding spacers at this point will increase the camber, and removal of spacers will decrease the camber.

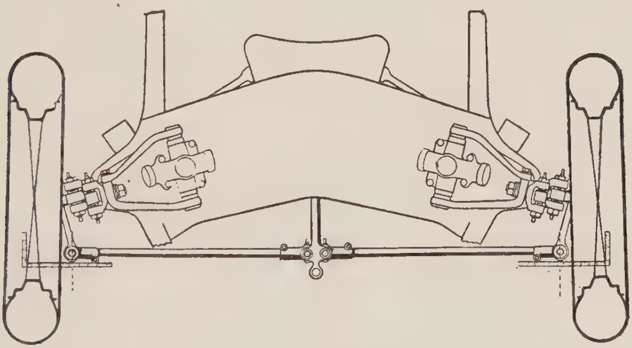


Fig. 19. Checking Steering Knuckle Arms with Steel Square

If, upon checking the camber angle, it is not within the specified limits, the king-pin pivot angle should be checked before attempting any adjustments to restore camber. The loaded height of the front springs should be uniform. To determine the loaded spring height, measure the distance from the top surface of each lower control arm, to the under side of the frame side rails, at the point where two rivets are located. This dimension should be $3\frac{1}{2}$ inches, plus or minus $\frac{1}{8}$ inch. If this distance is not uniform within the limits quoted, it must be corrected by the use of spacers under the front spring on the side of the car which is low.

Jack up the car, by the jack pad only, so that the weight is off the front wheel on the side of the car on which adjustments are to be made. This is necessary in order to obtain sufficient clearance at the upper yoke nut. Disconnect the tie rod at the wheel end, otherwise the tie-rod end will break, or the tie rod will become bent, when the upper yoke is disconnected. Remove the upper control-arm yoke nut, using the special wrench, and pull the yoke out of the shock-absorber arm. To increase camber, install washers between yoke and shock-absorber arm. To decrease camber, remove washers from between yoke and shock-absorber arm and place them on the inside face of the shock-absorber arm under the yoke nut. Install upper control-arm yoke in shock-absorber arm and tighten nut securely. Remove the car from the jack and check the camber. If it is not within the limits specified, repeat the operations. Caster and camber must be uniform within $\frac{1}{4}$ degree, at both front wheels.

Pivot (King=Pin) Angle. The steering-knuckle spindle is made at such an angle with the steering-knuckle king-pin pivot angle, that the total angle between the wheel centerline and the king-pin pivot centerline is 10 degrees. The king-pin centerline is also parallel to the centerline of the steering-knuckle support yoke pin-hole (Fig. 20).

If the steering-knuckle support should become bent, through accident, this would not only upset camber, but would cause a change to occur in the king-pin pivot angle. Camber should not be corrected by shifting the washers at the upper support yokes, without first checking the king-pin pivot angle. The king-pin pivot angle plus the camber angle, should be 10 degrees, plus or minus $\frac{1}{2}$ degree. This limit of $\frac{1}{2}$ degree plus or minus, is given for slight variations in machining and deflections due to loads. If this total angle is not correct, the steering-knuckle body or the vertical support is bent and should be replaced; otherwise excessive tire wear will result.

To Correct Wheel Tramp and High=Speed Shimmy. Wheel tramp and high-speed shimmy, in most cases, can be attributed to unequal tire pressures or an out-of-balance condition of the front wheels and tires, provided toe-in is correct, and camber and caster are uniform at both front wheels, and are within the recommended limits. Front wheels, tires and brake drums are balanced in production; but tire wear, blowout boots, and patches on inner tubes, if used, will necessitate rebalancing. *Wheels must be kept in balance.* When shimmy and tramp exists, the following operations should be performed. Adjust the front-wheel bearings. Proper bearing adjustment

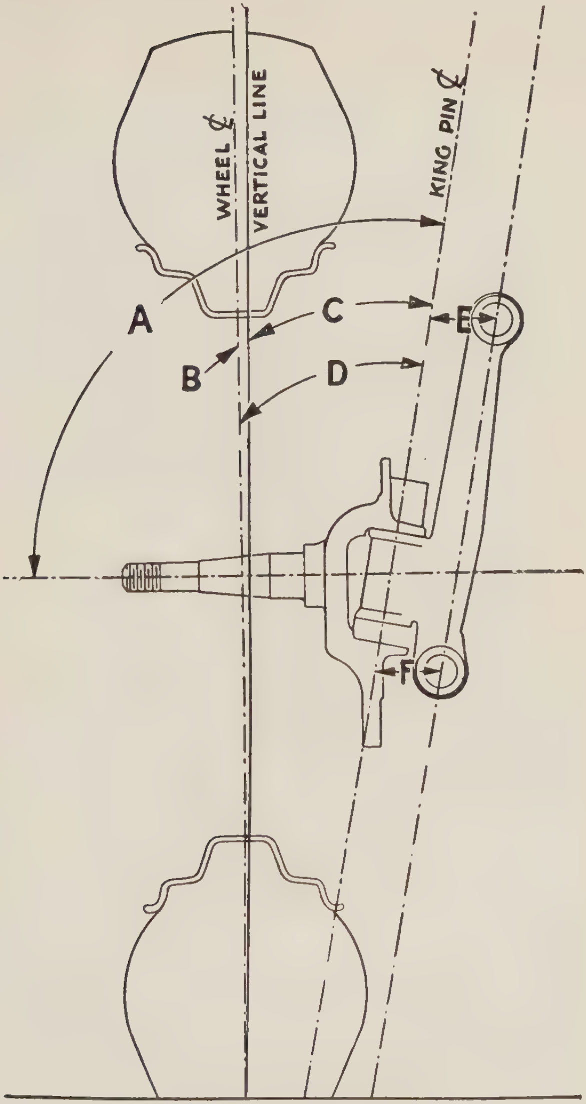


Fig. 20. King-pin Pivot Angle and Camber Angle A—100°, Plus or Minus ¼°; B—¼° to 1°, Camber Angle; C—8¾° to 10¼°, King-pin Pivot Angle; D—10°, Plus or Minus ½°, King-Pin Pivot Angle Plus Camber Angle; E is Equal to F because the King-pin Centerline is Parallel to the Centerline of the Steering-Knuckle Support Yoke Pin Hole Centers

should be made as follows: adjust the nut so that there is just sufficient bind to gradually stop the wheel from spinning. The nut should then be turned back one notch, to the nearest cotter-pin hole. King-pins and bushings which are excessively worn should be replaced. To test for wear, place one hand on top of tire and one at extreme bottom, and shake in and out. If there is $\frac{1}{8}$ inch or more free play, king-pins and bushings should be replaced.

Check both front and rear spring shackles for proper adjustment. They must be free-acting, but not loose enough to permit vertical or lateral movement, in other words, not sloppy. The steering shock eliminator must be free. Check the adjustment of the drag link ball joints. If the parts are excessively worn, they should be replaced. Check the tie-rod end assemblies for wear. Check the king-pin (pivot) angle. Check the caster, camber, and toe-in, in the order named, and make adjustments to specifications as required.

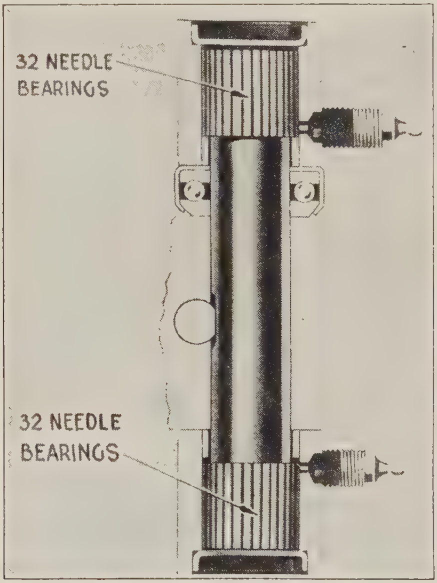


Fig. 21. King-pin Bearings

Check the fluid level of the shock absorbers, and add genuine, recommended shock absorber oil to bring the level to the top of the filler-plug hole. Check wheel and tire runout. Total wheel eccentricity should not exceed $\frac{1}{8}$ inch at the rim, and wheel wobble or runout should not exceed $\frac{1}{8}$ inch. Tire eccentricity should not exceed a total of $\frac{3}{16}$ inch at the tire periphery.

On cars with independent suspension, check the yoke pins and lower control-arm pins for wear, and replace if necessary. Check wheel, tire and brake-drum assembly balance. Rebalance if necessary, using balance weights of the type that clamp on the rim. Inspect steering gear and drag link for proper adjustment. Lubricate all parts properly. Road test the car.

Excessive tire wear, in most cases, is caused by misalignment, poor steering geometry, or under-inflation. Check steering geometry on a wee-gee board or similar wheel-aligning equipment. Determine if steering knuckles or arms are bent. For excessive rear tire wear, check wheels and tires, for runout and concentricity. Check frame and rear-axle housing alignment.

SERVICING THE CHEVROLET KNEE-ACTION FRONT-WHEEL SUSPENSION

In this construction, Fig. 15, a king-pin support is attached to the front end of a rigid frame, with special bolts, and the front-wheel and spring housing are mounted on king-pins at the end of this support. This allows the spring unit and wheel to turn about the king-pin. Thirty-two needle or roller bearings, Fig. 21, are placed on each end of the king-pin, to allow the spring unit to turn freely. Pressure-gun fittings provide the means of lubricating these bearings.

This spring unit consists of eight major parts as follows:

1. **Housing.** The coil springs and shock absorbers are protected within a waterproof steel case. Their original soft, quiet action is not impaired by exposure to dirt, mud and water. Genuine Chevrolet Shock Insulation Fluid fills the entire housing, supplying the shock absorbers and lubricating all of the working parts. All joints on the outside of the spring housing are sealed against leakage.

2. **Double-Action Shock Absorbers.** The upper shock absorber cushions the upward wheel travel, and the lower shock absorber cushions the downward travel. Their operation is similar to the conventional double-action shock absorbers.

3. **Main Coil Spring.** This heavy coil spring provides a smooth, cushioned riding action, much softer and far more accurately controlled than conventional type leaf springs.

4. **Secondary Coil Spring.** A smaller, stiffer coil spring within the main coil spring, automatically provides additional cushioning when required on exceptionally rough roads.

5. **Spring Adjustment.** Threaded plugs in the top of the housing permit close adjustments. When this proper adjustment is obtained, a special plate locks the plug in place.

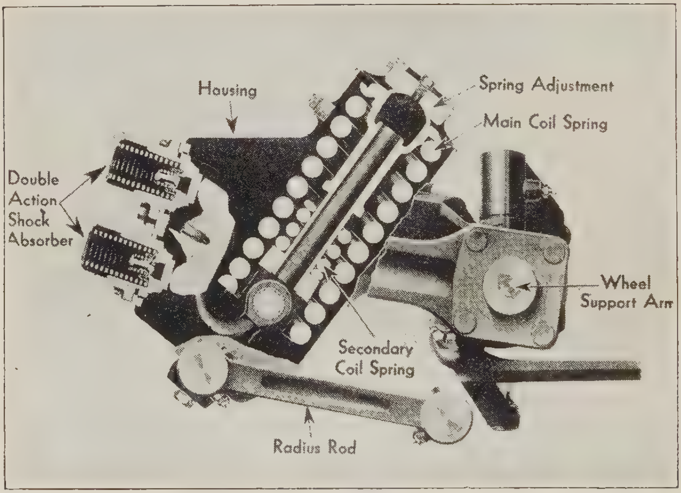


Fig. 22. Knee-action or Independent Front-wheel Suspension Unit

6. **Wheel Support Arm.** The front end of this heavy drop-forged alloy-steel arm, operates the coil springs and shock absorbers. The rear end supports the front-wheel spindle and front wheel.

7. **Radius Rod or Bracing Arm.** The radius rod or bracing arm is parallel to the wheel support arm, and swings on large threaded bearings, one on the brake flange plate and one on the spring housing, bracing the wheel and permitting the wheel to travel only straight up and down, and maintaining the brake flange plate and brake assembly in its correct position.

8. **Needle or Roller Bearings.** Needle or roller bearings are provided at all necessary points to permit free and easy action in the

knee-action and steering systems, under all conditions of load and position, Fig. 21. These needle bearings are quite like a straight roller bearing without cages, using rollers of comparatively small diameter, .093 inch. The bearing races, instead of being a part of the bearing itself, are the ground surfaces of the two parts between which the needle bearings are placed. In some cases the needles are held from end movement by an adjoining part butting against their ends. In either case clearance is allowed, to prevent binding. The name is derived from the comparatively small size of the rollers.

Operation of Chevrolet Knee Action. As the wheel moves upward, the front end of the wheel support arm contacts the main spring, Fig. 22, which takes the wheel load and cushions the movement of the wheel. This main spring functions for $1\frac{7}{8}$ inches of the upward movement of the wheel and arm, after which the small inner "bottoming" spring is compressed, building up the spring pressure and cushioning and stopping the shock from being transmitted to the car and occupants. At the same time the front end of the wheel support arm contacts the upper shock absorber, which also cushions the movement of the wheel.

The lower shock absorber cushions the wheel and the support arm on its downward movement. The main coil-spring pressure forces the wheel downward and forces it to follow the road.

Specifications. The king-pin inclination is 7 degrees, the camber (with load on wheels) is 1 to $1\frac{1}{2}$ degrees, the caster 0 degrees, the toe-in $\frac{5}{64}$ inch to $\frac{1}{8}$ inch and the tread $56\frac{1}{2}$ inches. The wheel setting from the top of the king-pin support to the top of the brake flange plate is $2\frac{1}{2}$ inches and from the bottom of the king-pin support to the bottom of the brake flange plate is $5\frac{1}{2}$ inches.

Care of the Chevrolet Knee Action. At least every 1000 miles, the level of the shock insulation fluid in the spring housing should be checked and the proper amount of genuine Chevrolet Shock Insulation Fluid added to bring the level up to, and even with the filler plug on the front of the housing. Genuine Chevrolet Shock Insulation Fluid is recommended for this purpose, as it will retain its fluid characteristics when the temperature is as low as 40 degrees below zero.

Pressure-gun fittings on the king-pin and radius rod, provide the means of lubricating these points. They should be lubricated with chassis lubricant every 1000 miles. High pressure equipment should not be used on the king-pins, as this will force the plugs from the ends of the king-pin boss. At least every 10,000 miles the front spindle bushing should be lubricated. To do this, remove the plug at the inner end of the spindle and pack the reservoir with a lubricant such as vaseline or petrolatum. Passages from the reservoir carry the lubricant through the spindle to the bearing surface. Pressure should not be used at this point.

Removing the Chevrolet Spring Unit. Jack up the car and remove the front wheel. Remove the two bolts and the lock plate at the bottom of the front-spring housing. Turn the unit outward and then lift off the brake assembly, holding the radius rod to prevent it from falling and striking the floor.

Remove the steering arm nut with the special wrench available for this purpose, and drive out the steering arm with a brass drift. Remove the king-pin lock pin and remove the lower king-pin bearing plug by driving down on the center of the upper bearing plug with a center punch. After this lower plug has been removed, drive the king-pin and upper bearing plug through the top of the king-pin yoke, using a brass drift to prevent damage to the king-pin.

During the operation of removing the king-pin, the needle or roller bearings will begin to fall out of the lower support boss. When the king-pin has been removed, be sure and pick out the remaining bearings from the lower support boss, and all of the bearings from the upper support boss. After this has been done, the front-wheel suspension or spring unit can be removed or lifted from the king-pin support.

Replacing Chevrolet Front=Spring Unit. Assemble the front-spring unit to the king-pin support, and start the king-pin in at the bottom, being sure that the longest end of the king-pin, from the slot, is at the top and that the slot in the king-pin lines up with the lock pin hole. Tap the king-pin thrust bearing into place, using a hammer with a soft head for this operation. The king-pin thrust bearing must always be assembled between the upper support boss and the top of the spring housing or steering knuckle, with the dust shield side towards the top. Check the end play between the spring housing or steering knuckle with a feeler gauge. If this is over .006 inch, insert a steel shim at this point. To properly assemble and be sure that the right amount of needle or roller bearings are assembled in both ends of the king-pins, a special tool is needed.

After the bearings have been inserted, assemble the king-pin bearing plugs and drive them into place. Lock both these plugs by upsetting the edge of the support boss with a center punch. Assemble the brake flange plate to the spindle, with the cork gasket removed. Assemble the thrust washer to the dowel, and check the clearance from the edge of the shoulder on the spindle, to the face of the thrust washer. This should not exceed .002 inch to .004 inch. In the event that this clearance exceeds these limits, place a shim between the hub of the brake flange plate and the thrust washer. After this clearance is obtained, remove the thrust washer and the brake flange plate. Assemble the cork gasket or washer, to the inside of the brake flange plate. This gasket should be coated with heavy oil or grease. Assembling the cork gasket onto the hub, eliminates any chance of having the gasket damaged by the dust shield. Assemble the brake flange plate to the spindle, and assemble the thrust washer onto the spindle and to the dowel in the brake flange plate assembly. Thoroughly coat the cork gasket with heavy oil or grease, and assemble it to the dust shield. Assemble the bearing spacer to the brake flange plate so that the "tang" on the bearing spacer engages the slot in the spindle, and assemble the inner bearing cone, being sure that it is centered in the thrust plate. Assemble the front wheel to the spindle.

Connecting the radius rod to the spring housing requires careful attention. First screw the radius rod bracket up tight on the radius rod. Then bring the radius rod straight up, without moving it to either side. Loosen the bracket just enough to line it up with the boss on the front spring housing. Then place it in position on the boss and assemble the lock plate and tighten the two radius-rod brackets to housing bolts securely.

Fill the front spring unit with genuine Chevrolet Shock Insulation Fluid. Lubricate the king-pins and radius rods. Never use high-pressure gun equipment in lubricating king-pins, as this equipment might force the king-pin plugs from the king-pin support bosses. Pressure should not exceed 2500 pounds. Remove the plug at the back of the front wheel spindle and fill the reservoir with vaseline or petrolatum. Drive the car over rough roads to check the action of the front wheels, as well as to work the shock insulation fluid into the shock absorbers. After the car has been driven over rough roads, check from the bottom of the king-pin boss to the bottom of the brake flange plate on each wheel. This should check $5\frac{1}{2}$ inches. If this dimension is either more or less than this, adjust the inner plug at the top of the spring housing, until it is the same on both sides, within $\frac{1}{8}$ inch. Seal the adjusting plug with Permatex and assemble the bolt and lock. If it is necessary to adjust any unit more than $\frac{1}{32}$ inch, replace the unit.

STUDEBAKER INDEPENDENT FRONT-WHEEL SUSPENSION

The drop-forged type of front axle "I" beam has been eliminated in the 1935 "Dictator" (2-A), "Commander," and "President" cars, and the front wheels are independently suspended at each end of a flat, multiple-leaf transverse spring, Fig. 23, which is provided with metal spring covers. The steering linkage in all of the 1935 model cars has been changed to a type similar to that termed "center steering."

The steering knuckle in the "Dictator" (2-A), "Commander" and "President" is mounted on a knuckle pin which is pivoted in bronze bearings in the steering knuckle support, Fig. 23. Thrust loads are carried on a combination of steel and bronze washers. The lower portion of the steering-knuckle support is hinged to the front spring with a conventional threaded type shackle pin. The upper end of the steering-knuckle support is linked to the frame by the steering-knuckle support arm. The outer end of the support arm is mounted on needle-point roller bearings which are sealed against dirt and water. The inner end of the support arm is mounted in live-rubber bushings which are carried in a housing bolted to the frame. The steering-knuckle support arm locates the upper end of the steering-knuckle support, and absorbs the braking torque.

The front spring is secured to the frame at its center, in an accurately machined channel or box section, and is clamped in place by a plate which is bolted to the under side of the frame spring channel. With this construction, the center of the spring is allowed free and active movement. Spring action is controlled by automatic thermostatically adjusted Houde shock absorbers. A stamped steel control link is in-

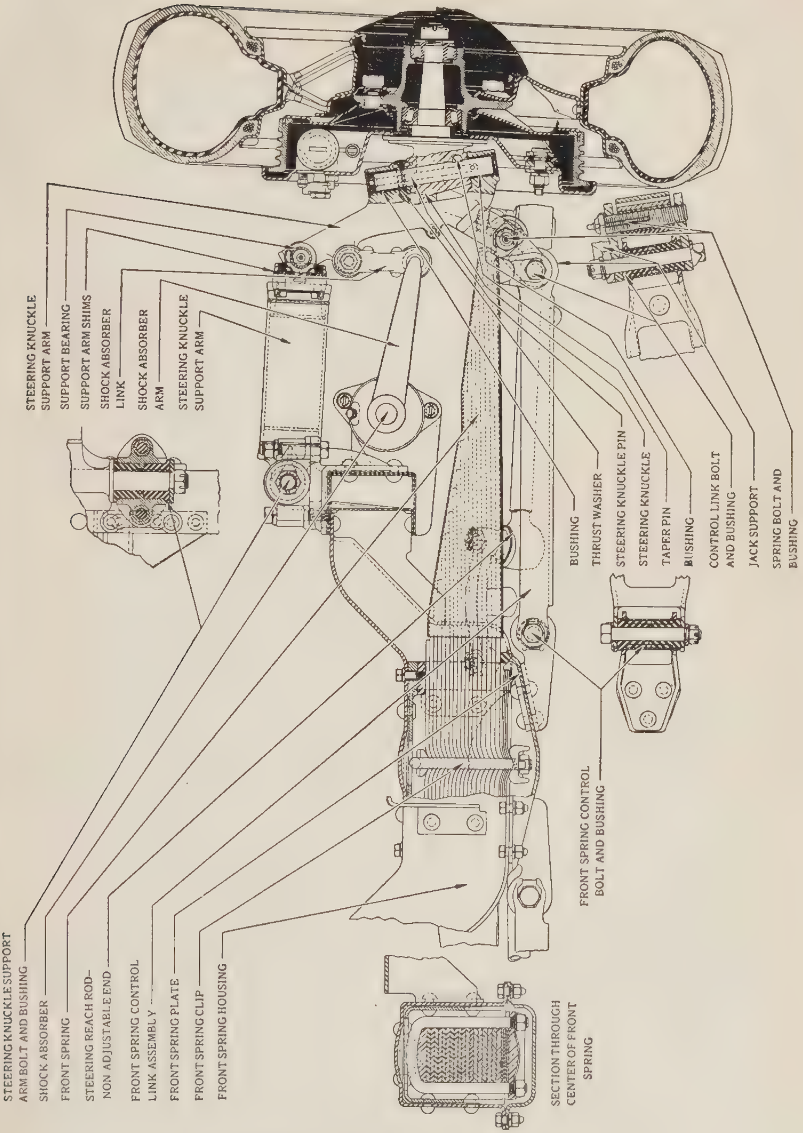

STEERING KNUCKLE SUPPORT ARM
SUPPORT BEARING
SUPPORT ARM SHIMS
SHOCK ABSORBER LINK
SHOCK ABSORBER ARM
STEERING KNUCKLE SUPPORT ARM
BUSHING
THRUST WASHER
STEERING KNUCKLE PIN
STEERING KNUCKLE
TAPER PIN
BUSHING
CONTROL LINK BOLT AND BUSHING
JACK SUPPORT
SPRING BOLT AND BUSHING
FRONT SPRING CONTROL BOLT AND BUSHING
STEERING KNUCKLE SUPPORT ARM BOLT AND BUSHING
SHOCK ABSORBER
FRONT SPRING
STEERING REACH ROD-NON ADJUSTABLE END
FRONT SPRING CONTROL LINK ASSEMBLY
FRONT SPRING PLATE
FRONT SPRING CLIP
FRONT SPRING HOUSING
SECTION THROUGH CENTER OF FRONT SPRING

Fig. 23. Sectional View of Studebaker Front-end Assembly

corporated beneath each end of the transverse spring. The inner ends are attached to the spring plate, which is bolted to the frame, and extend under the front spring to the lower end of the steering-knuckle supports. The control links are mounted in live-rubber bushings. The control links insure absolute control in the event of spring failure, and serve as a support for a jack or lift, when raising the front of the car.

The steering gear is mounted on the frame side member. The steering gear cam lever shaft projects downward and is serrated for attachment of the steering drop arm which extends forward from the shaft. The steering drop arm is connected directly to both steering-knuckle arms, through a short, non-adjustable reach rod on the left side, and through a longer adjustable reach rod on the right side, on left-hand control cars. The entire design is such that each front wheel is permitted its independent and natural action without relationship to the other wheel.

Front-Wheel Camber. The specified wheel camber is from 1 to 1½ degrees. Wheel camber should be checked with the car unloaded, on a level floor or platform, and with the tires properly inflated. Before checking, the car should be bounced up and down several times by grasping the front bumper, to insure that the wheels are in their natural running position.

The camber can be increased by adding, or decreased by removing, the shims, which are located between the steering-knuckle support arm and the steering-knuckle support arm outer bearing, Fig. 23. The shims provided for this purpose are $\frac{1}{32}$ inch thick. One thickness of shims changes the camber ¼ degree. The use of a maximum of six shims is permissible.

Front-Wheel Toe-In. The specified front-wheel toe-in is from $\frac{1}{16}$ inch to ⅛ inch. Toe-in adjustment is made by changing the length of the longer steering reach rod. Loosen the two clamp bolts, one at each end, and turn the reach rod which has a right-hand thread on one end and a left-hand thread on the other. Due to the angle of the steering reach rods, it is necessary that the toe-in be checked whenever the steering wheel position is adjusted for height (raised or lowered) to suit the requirements of individual owners.

Caster. The caster is determined by the relation of the front spring to the frame. The spring is located in a channel in the frame, accurately machined at the factory, to provide a caster angle of from a minus ¼ degree to a plus ¾ degree with the car unloaded and level, and with the tires properly inflated. The caster angle cannot be adjusted from its original factory setting.

Spring Camber. The design of the new Studebaker front-end suspension is such that a considerable variation in front-spring camber is possible without affecting the steering characteristics of the car. In the event, however, a check for spring camber is considered desirable, the spring camber can be determined easily by stretching a cord between the two spring-bolt centers, as shown in Fig. 24. If the cord is not more than ⅜ inch above the dividing line of the spring retainer plate and housing, the spring is still serviceable. A measurement of more than ⅜ inch at this point will indicate excessive spring sag.

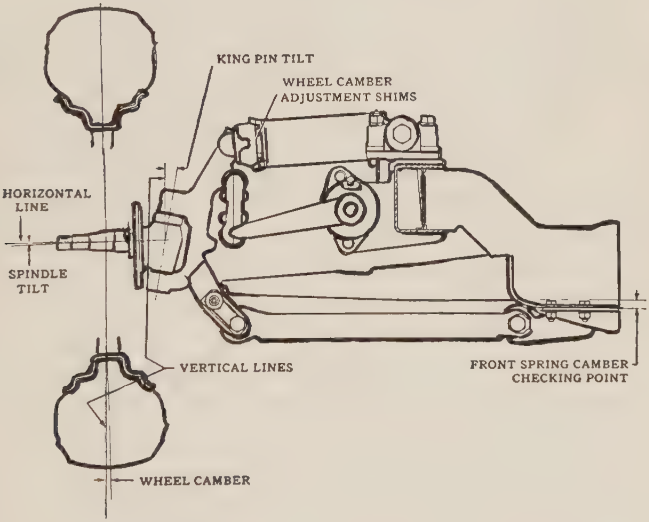


Fig. 24. Front-end Alignment Chart—"Dictator," "Commander," and "President"

Lubrication of the front wheel suspension should be thorough at regular intervals. Always make certain that the steering connecting rods, the steering tie rods, and the knuckle pins are lubricated through their pressure fittings each 1000 miles. Use Chassis Lubricant *S* for summer and Chassis Lubricant *W* for winter.

OLDSMOBILE FRONT END SUSPENSION

In the 1936 Oldsmobile front end suspension the lower control arm design has been greatly improved, eliminating the upper and lower control arm yoke. This has decreased the unsprung weight, because of the elimination of the upper control arm yoke, and caster and camber adjustments have been greatly simplified.

All steering adjustments should be made at curb weight, that is, without passengers or load in the car, but with the spare tire and wheels in place, and filled up with gasoline and water.

The following are the specifications for the steering condition: caster, 1½ degrees to 2¼ degrees; camber, ⅛ degree to 1 degree; toe-in, ⅛ inch to 3/16 inch; king-pin inclination, 5 degrees 51 minutes.

BUICK FRONT WHEEL ALIGNMENT

For accurate checking of toe-in, camber and caster, and steering geometry, the car should be empty of passengers and with no load in the car. Spare tires should be in place, and the car should be full of water, oil and gas. The tires should have about the same amount of wear, and should be inflated to the correct air pressure, which is 26 pounds on the 40 series and 28 pounds on the 60-80-90 series. The front springs should be equally extended on both sides to curb height, which is 4 9/16 inches for the 40-80-90 series and 4¾ inches on the 60 series. If the front springs are too short or too long, by a quarter inch, or if one side is higher or lower than the other by a quarter inch certain adjustments must be made before steering adjustments can be carried out.

An incorrect stabilizer or frame condition may cause the car to lean to one side. To check the stabilizer, disconnect one of its links. If this does not bring the car level, the springs must be tested for length by placing the two springs side by side on a flat surface. With the springs free, they should be exactly the same height. Shims may be used to bring the two springs to the same free height. Such shims come in ⅛-inch thickness. If more than two shims are required on the low side to bring the free height equal, the trouble may be in the rear springs or in the frame. More than two shims will cause the low side spring to carry more than its load, and it will quickly sag. Where such shims are used, they should be placed at the top of the spring and next to the spring.

FRONT SUSPENSION—FRONT AXLES—STEERING GEARS

PART II

FRONT AXLES

Classification. Generally speaking, front axles may be divided into two classes: the Elliott and the so-called reversed Elliott.

Elliott Type. In general, a front axle consists of a bed, or axle center; a pivot pin or knuckle pin upon which the knuckles may turn; and the knuckles with the attachment for turning them. The Elliott type, Fig. 25, is the form in which the end of the axle takes a U-shape, is set horizontal and goes over the knuckles. The knuckles have plain vertical ends bored for the pivot pin, which passes through and has its bearing in the upper and lower halves of the axle jaw. In this form, the thrust comes at the top, where the axle representing the load rests upon top of the knuckles that represent point of support.

Reversed Elliott Type. In the reversed Elliott front axle, as the name would indicate, the action is just reversed in that the axle end forms a straight vertical cylindrical portion bored for the pivot pin, while the knuckles are so formed as to have yoke ends which go over the axle ends. The thrust comes at the bottom of the knuckle, where the axle bed rests upon the upper face of the lower jaw of the knuckle, the axle representing the load and the knuckle the support, just the reverse of the previous case.

This will, perhaps, be made clearer by illustrations. In Fig. 25, the axle has the yoke ends, and the thrust comes at the top. This is indicated in the figure by the steering knuckle thrust bearing and the thrust washers at the top. Fig. 26 shows an axle of the reversed Elliott type, this being the front axle of conventional design. In this the thrust washers are at the bottom of the axle beam ends, and are of hardened steel, ground top and bottom to a true surface.

Hudson-Terraplane Radial Control Front Axle. The axle beam is of the Elliott type, the center section being a heavy dropped forging

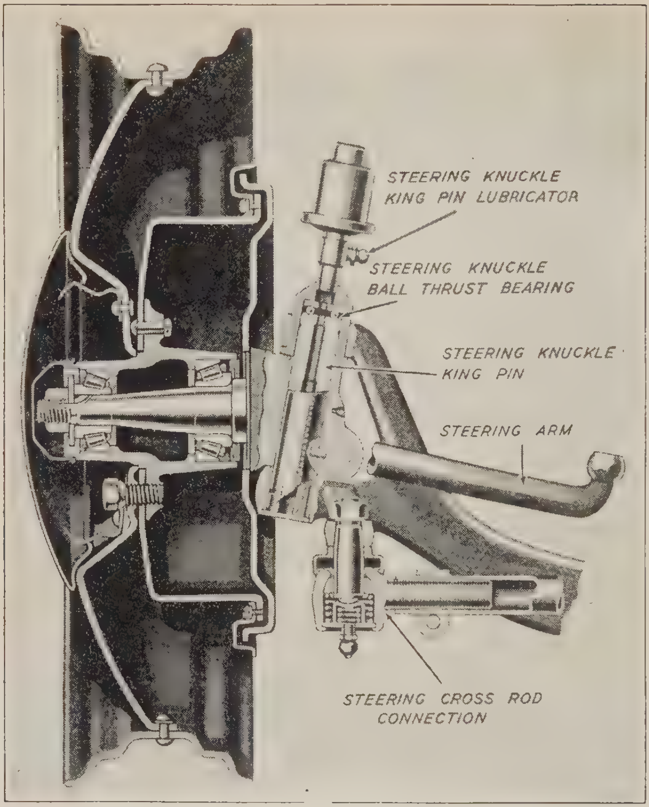


Fig. 25. Elliott Type of Front Axle and Steering Knuckle
Courtesy of Hudson Motor Car Company

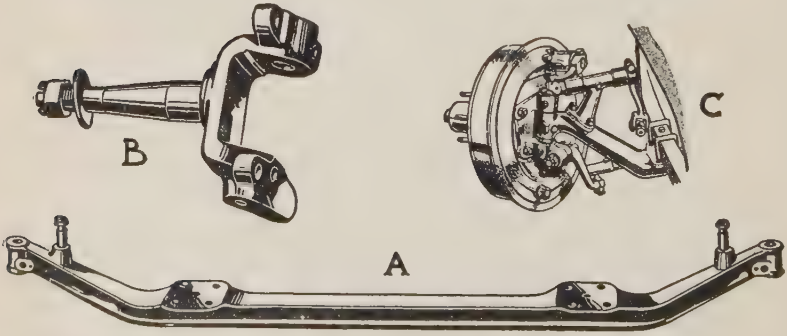


Fig. 26. A—Conventional I-Beam Front Axle; B—Elliott-type Steering-Knuckle Body and Spindle Assembly; C—Conventional Front-Axle Design

of high quality carbon steel. The steering knuckle spindles are drop-forged molybdenum alloy steel and are attached to the axle center with alloy steel spindle pins which are mounted in hardened steel bushings with ball bearings to carry the thrust on the end of the pin. The unique feature in the design of this axle, as illustrated in Fig. 27, is the use of the two torque arms, which are used to insure the accurate alignment of the axle with the frame and to relieve the front springs of all loads other than that of carrying the weight of the car and passengers. The torque arms are attached to the frame through large rubber bushings in the mounting brackets which are used to absorb road shock. The suspension is designed to allow the front axle to oscillate in the spring perch mounting bracket which clamps over a cylindrical section of the axle I-beam. The vertical alignment of the king pins is maintained by the radius arm control which serves to propel the front axle while maintaining it in frame alignment at all times. When spring action occurs, as under load or rebound, the free ends of the spring move outward from the central axle mounting bushing, since they are shackled both front and rear. The radius arms are mounted to the axle beam in such manner as to prevent any motion between the forward end of the radius arms and the axle beam. Thus, it will be seen that when torque is developed on the axle when

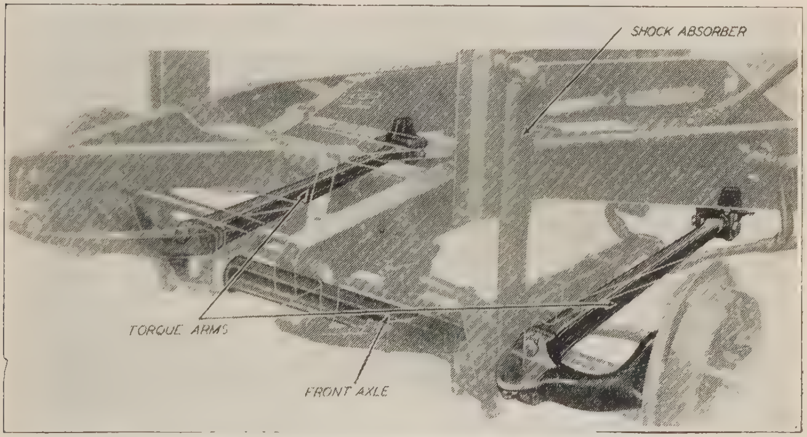


Fig. 27. Terraplane Radial Control Front Axle

the brakes are applied, this is transmitted immediately through the radius arm to the car frame rather than coming from the axle beam to the front springs and thence to the car frame, as is the case with more conventional front end suspension.

Front Axle Materials. Steels used in front axles are of special formula, either being of the vanadium type, nickel, or chrome nickel specifications. Since most of the front axle parts are produced by means of the drop-forge hammer, where expensive dies are utilized, it is necessary to have a material which lends itself to the drop-forge process. At the same time this material must also be subjected to proper heat treating, in order to induce within it great strength and toughness. Specifications for certain parts of the front axle, as for instance the steering knuckle, *B*, Fig. 26, the steering knuckle pivot pin or king-pin and the front axle beam, *A*, Fig. 26, will vary accord-

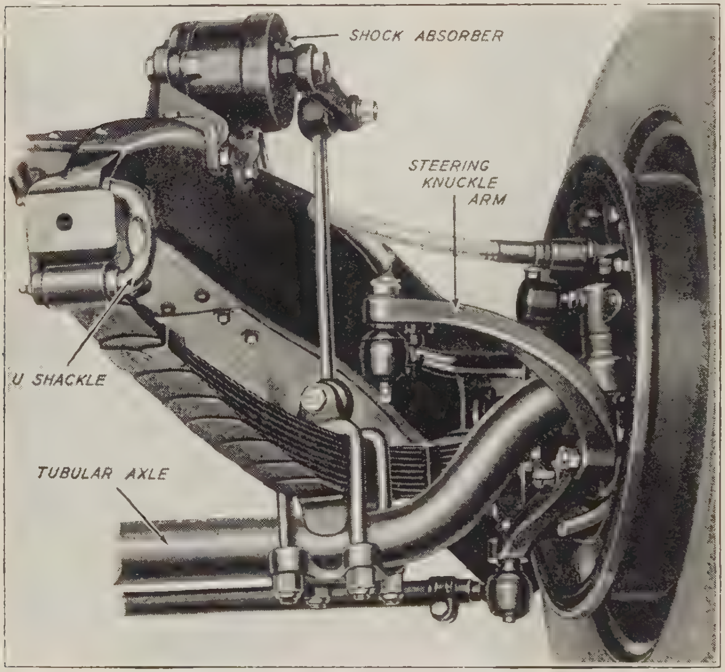


Fig. 28. Tubular Type Front Axle

ing to the uses to which these parts are to be put, and the degree of hardening and tempering desired.

I=Beam Front Axle. The I-beam section of the front axle is usually used. An axle of this type is illustrated at *A* in Fig. 26. After the I-beam section has been blanked out on the drop-forge dies, it is sent to the machine shop where all machine operations are performed on it. Heat treating, as a rule, comes afterwards, although it might be performed first. There is a very definite relation between the spring pad surfaces, the king-pin inclination, the caster, camber, and other features of front axle design which are so essential to proper performance of the automobile on the road. All of these features are discussed at a later point.

Tubular Axles. Fig. 28 illustrates a section of a tubular front axle. Tubular front axles have long been popular with certain manufacturers. They lend themselves both to lightness and strength. Manufacturing operations, of course, are quite similar to those for the drop-forged I-beam, insofar as machining of the parts in order to secure the proper front axle geometry is concerned. Certain features of the tubular front axle, as for instance attaching the spring pads, lend themselves to production by the welding process.

THE CHEVROLET TRUCK AND PASSENGER CAR THROUGH=TYPE FRONT AXLE

Construction. This axle, Fig. 26, is known as the reverse Elliott type. It is a steel drop forging with the spring seats forged integral with the I-beam. The I-beam is heat-treated for extreme toughness, and is machined to very close limits. The king pin is slotted and held in position by a tapered pin which is drawn tightly into the slot by a lock washer and nut. The holes at each end of the I-beam are bored at a slight angle to permit the king-pin to tilt inward at the top. This inward tilt is called king-pin inclination. The steering knuckle is mounted to the front axle by means of this king-pin and rides on a ball bearing which makes steering easy.

The brake flange plate is securely bolted to the steering knuckles and carries the brake shoes and their cam operating levers. The steering-knuckle arms are also bolted to the steering knuckle, and are connected with each other by the tie rod. The tie rod is the adjustable type which is attached to the knuckle arms, and controls the amount of gather or toe-in of the front wheels. The third arm for the drag link connection is forged integral with the left knuckle and is connected to the pitman arm through the steering connecting rod.

A caster shim or I-beam spacer is inserted between the front springs and the front axle. The installation of this shim controls the amount the top of the axle inclines rearward. This rearward tilt of the axle gives the front wheels their caster. The front wheel spindles, which are forged integral with the steering knuckles, are tilted downward at their outer ends, thus causing the front wheels to be farther apart at the top than they are at the bottom. This slight angular position of the front wheels is called camber.

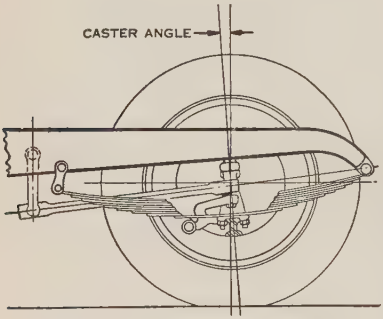


Fig. 29. Caster Angle

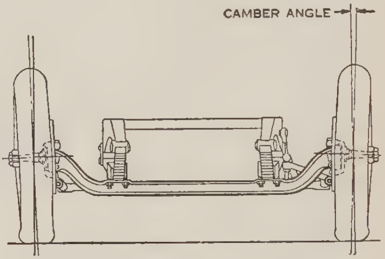


Fig. 30. Camber Angle

The steering-knuckle arms are installed on the knuckles at an angle, permitting the front wheels to toe out when making turns. This set up is necessary, due to the fact that in turning curves, each wheel must travel in a different arc. This toe-out on curves is known as steering geometry. These five front end factors are built into the axle and must be in proper relation to each other to prevent steering faults and excessive tire wear.

Caster. Caster is the amount in degrees, of the backward tilt of the axle and king-pin. See Fig. 29. A car without caster would lack steering stability and would tend to wander over the road. Unequal caster shows itself in the tendency of the car to pull to the right or left. This condition comes about through the axle having been twisted so that there is a greater amount of caster in one king-pin than in the other. The direction in which the car will tend to pull is towards the side with less caster. Suppose that an accident has put a twist into the front axle so that the left side is zero caster, while the right side is castered backward five or six degrees, the right wheel will have a strong tendency to turn inward, pulling the car to the left. Axles having no caster, result in a car that is difficult to steer, that tends to pull to the right or left and will turn a corner easily but is hard to straighten out at the end of the curve.

Camber. Camber is the amount in inches or degrees, that the front wheels are tilted outward at the top. See Fig. 30. When a wheel has too much camber, that is the wheel is tilted too far out at the top, the tire is forced by road contact into a conical shape, on its under side. The result would be excessive tire wear on the inner edges of the tread. The center of the tread would remain comparatively unworn. The rule is that if wheels have the maximum amount of allowable camber, they must have the maximum amount of allowable toe-in. If wheels have the minimum amount of allowable camber, they must have the minimum amount of allowable toe-in.

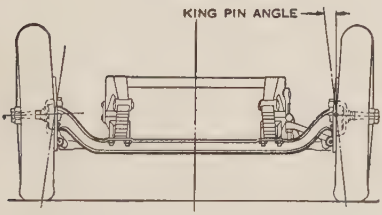


Fig. 31. King-Pin Inclination

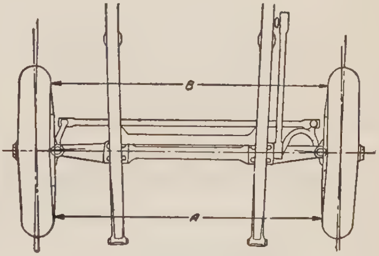


Fig. 32. Toe-in

King-Pin Inclination. King-pin inclination is the amount in degrees that the tops of the king-pins are inclined toward the center of the car. See Fig. 31. King-pin inclination tends to keep the wheel spindles pointed outward, in line with the axle, just as caster tends to keep the wheels of an automobile pointed straight ahead. The effect is the same, since if the spindles are kept pointing out at right angles to the car, the wheels will, as a result, be kept pointing ahead. It makes the car steer easier.

We have already referred to the close relationship between the factors that enter into the front-axle assembly. It is a point that cannot be overstressed. One must keep this close interrelation constantly in mind, to gain a full and true understanding of this cleverly designed mechanism. And especially in order to correct any wrong adjustment, it is necessary to realize what effect a change in one element of the mechanism may have on the operation of the other parts.

Toe-In. Toe-in is the amount in inches that the wheels toe-in, that is, the distance between the front wheels *A*, Fig. 32, is less at the front than it is at the rear, *B*. Cambering the wheels out at the top makes it necessary to draw them in at the front.

Toe-in is a necessity growing out of camber, and directly related to it. It might seem that since the wheels are headed inward toward the center of the road, while actually traveling a parallel course, there must be a constant grinding of their surfaces on the road surface. It would appear that they are being held apart constantly by the axle, against their tendency to roll outward to the same point. As a matter of fact, it is to avoid this tire-wearing surface grind that toe-in is employed. Just as the purpose of camber is to give the wheel a setting so it will be in as nearly a balanced free running position as possible; so with toe-in, the purpose is to set the wheel in a position to reduce to a minimum the road friction on the tire.

Steering Geometry. Steering geometry, Fig. 33, is the mechanics of keeping the front wheels in proper relative alignment as the wheels are turned to the left or right. The front wheels, when the car is making a turn, are not on the same radius line, drawn from the center around which the car is turning (Fig. 34) and, because of this it is necessary for the front wheels to assume a toed-out position when rounding curves. This position is governed by the angle of the steering arms.

On the curves, the wheels of any vehicle, if properly set, will be at a right angle to the radius line from the center around which the car is turning. Therefore the left or inside wheel must be at right angles to the radius line *C*, which passes through its spindle and strikes the lines from the other three wheels at *D*, Fig. 34.

The accuracy of the steering geometry is governed by the condition of the steering arms. For example, suppose a steering arm has been bent, by bumping a wheel against a curb, in such a way as to cause the right wheel to toe-in excessively when the car is turned around a corner; this tire would drag, causing rapid wear. This condition accounts for the cars we see once in a while, that persist in wearing out one front tire twice as fast as the other, although by the usual tests, the wheels are perfectly set for straight ahead driving.

In Fig. 34 is a diagram of a car making a left turn. The right wheel is set at an angle of 20 degrees, the angle being exaggerated to bring out the principles more clearly. A line *A* drawn through the rear axle and a line *B* drawn through the spindle of the right wheel, and a line *C* drawn through the spindle of the left wheel, meet at *D*, which is the center around which the car is turning.

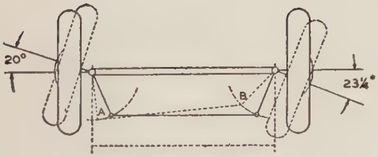


Fig. 33. Steering Geometry

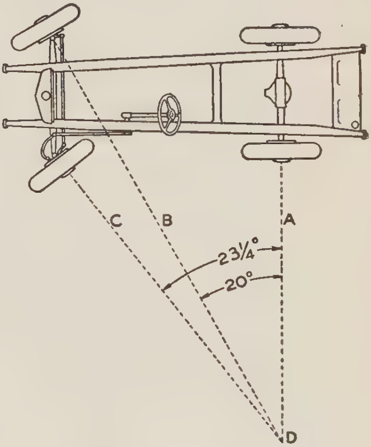


Fig. 34. Toe-Out on Curves

Specifications. The caster of standard models and master half-ton trucks is 1¾ degrees. Of the master 1½ ton trucks, the caster is 2¾ degrees. The camber is 1 degree; the king-pin inclination, 7 degrees, 10 minutes; and the toe-in is 5/64 inch to ⅛ inch.

Repair Operations. When service men thoroughly understand the foregoing information, they will appreciate the accuracy necessary when checking the front-end system. There are several different kinds of equipment by which these operations can be performed. It must be remembered that no matter what kind of equipment is used, all of these checks must be made with the car level, with the weight of the car on the wheels, and with no load in the car or truck.

Bad steering performance may be due to some cause not connected with front-wheel alignment. Therefore, check to see that none of the following conditions are present, before placing the car on the front end machine: 1—loose steering, 2—steering housing loose on frame, 3—play in king-pins, 4—loose tie rod or steering connections, 5—loose shackles, 6—loose front spring U-bolts, 7—front spring slipped on saddle due to sheered tie bolt, 8—over-lubricated front springs, 9—sagging or broken front springs, 10—under-inflated tires, 11—unbalanced or mismounted tires, 12—motor mountings improperly adjusted, 13—broken motor mountings, 14—motor not properly tuned, 15—brakes dragging, 16—hub bolts loose, 17—shock absorbers not operating properly.

After this inspection is completed and the conditions corrected, the car should be placed on the front end machine and checked. There are several types of front end machines on the market, using different mechanical means for locating and correcting front end troubles. One of these is pictured at the front of this section. The instructions furnished by each manufacturer for the operation of his particular machine should be followed.

Adjusting the Toe=In. As mentioned previously, there are a number of devices which are used for determining the condition of the front axle with reference to the maintenance of the correct caster, camber, toe-in and axle geometry. Not all shops have access to this type of equipment, and there are a number of operations which may be performed in the smaller shops with a minimum of equipment. When adjusting the toe-in, simple equipment such as that illustrated in use in Fig. 35, at *2*, may be used for checking the tire centers. Another piece of inexpensive equipment is that illustrated at *3* and used in illustrations *4* and *5* for checking the toe-in. Bear equipment illustrated at *6* of the same figure, is in use quite generally. When used, it is placed with the legs of the yoke in contact with the felloe of the wheel. The readings are then made on the dials where the pointer is noted. The spring serves to keep the yoke ends in contact with the wheel felloes. The actual matter of adjusting the toe-in, is accomplished by means of screw threads on the front-axle tie rod, illustrated at *1*, Fig. 35.

As explained previously, the amount of toe-in is dependent upon the camber and other front-axle features. Consult the specifications of the car manufacturer before attempting to adjust the toe-in. The measurement *J* is always less than the measurement *K* (see *1*, Fig. 35). A check up on the front axle should show that the measurements *M* are equal. When checking the toe-in, the measurements may be made on a center line on the tires as indicated by the letter *B*, illustration *1*, Fig. 35, or the points *J* and *K* may be used, or the two points *X* and *Y*. The closer the measurements are taken to the center of the

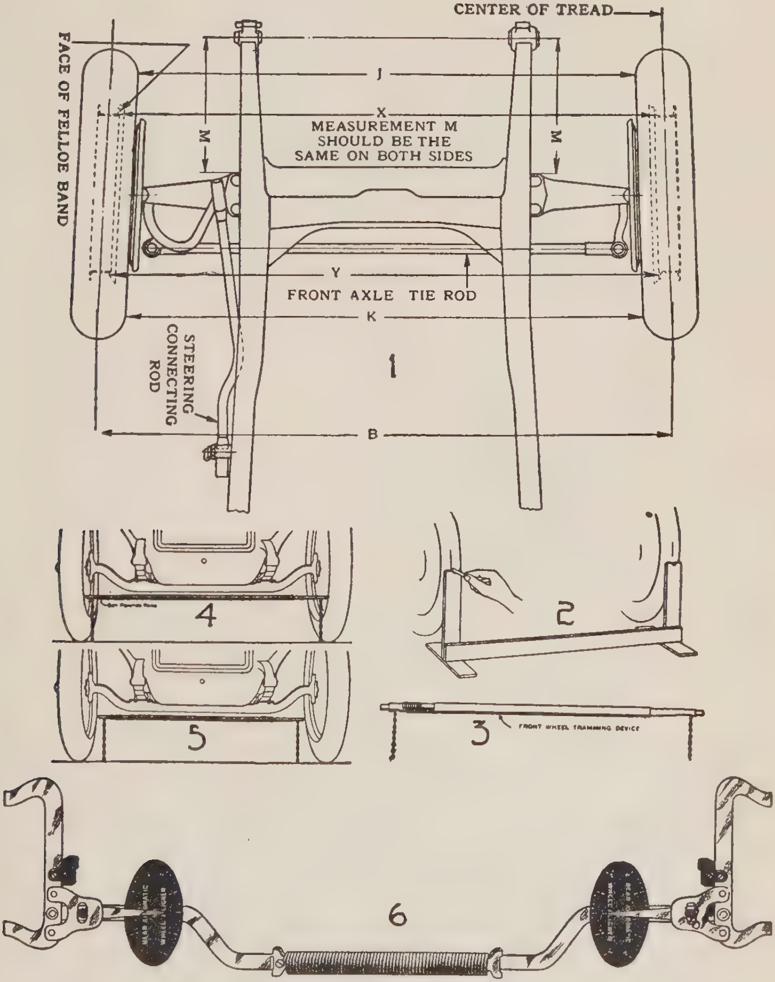


Fig. 35. 1. Measurements for Toe-in; 2. Marking the Front Tires; 3. Tool for Measuring Toe-in (Tramming Tool); 4. and 5. Tramming Tool in Use; 6. Bear Front-Wheel Aligning Tool

wheel, the less difference there will be between the two. For instance a specification which asks for $\frac{1}{8}$ inch difference on the tire tread would find possibly $\frac{1}{16}$ inch difference on brake drum rim.

In using the simple device illustrated at *3*, Fig. 35, it is first placed at the front of the car, in position as shown at *4*, the ends of the chain just touching the floor. Notation is made of the measurement, and the car is then rolled forward until the ends of the chain are just touching, with the device in the rear position as shown at *5*, Fig. 35. The difference in measurements is indicated on a graduated scale of the device, so that results may be read directly.

Correcting Caster. As indicated at *A*, Fig. 36, caster has to do with the center line of the axle I-beam, or the center line of the king-pin as shown at *B*. In *A*, Fig. 36, it will be noted that there are two lines, *XY*, and *XZ*. *XZ* is a vertical line and *XY* is the center line of the axle. Note that the center line of the axle is inclined toward the rear at the top, as compared with the vertical line. This same condition is also shown at *B* where the plumb line indicates that the top of the king-pin inclines to the rear. Since the king-pin and the center of the axle are in the same plane, the same result is secured at each point.

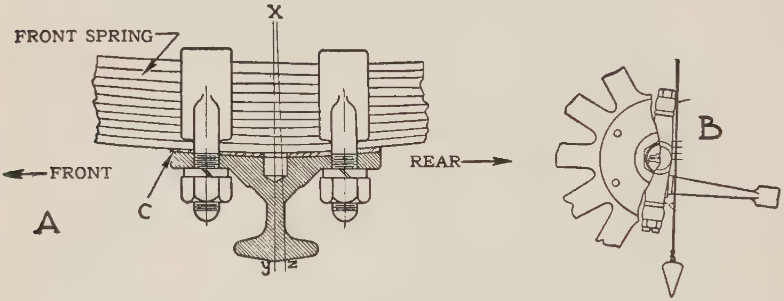


Fig. 36. Using Wedge Shims to Secure Caster

If for any reason, caster has been lost from the axle, it may easily be secured by installing a wedge similar to the one indicated at *C*, Fig. 36. Note that the front of this wedge is thinner than the rear portion. This is installed under the front spring. Wedges are provided, by car dealers and supply houses, with a varying number of degrees of taper. In this manner it is possible to secure almost any desired caster angle for the king-pin. Sometimes a car will be found which is difficult to steer because of the fact it is prone to shimmy. In such case it is sometimes possible to remove the shimmy by reversing the wedge under the front spring, if too much caster has been provided.

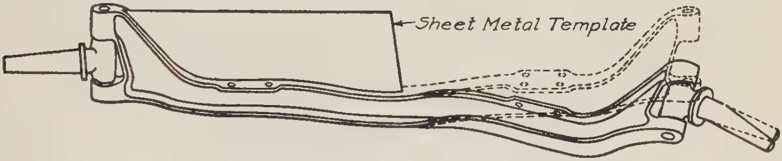


Fig. 37. Template for Showing if Axle Is Bent

Straightening an Axle. When an axle is bent, as in a collision, a template is useful in straightening it. This can be cut from a thin sheet of metal, light board, or heavy cardboard. It is an approximation at best and should be used with great care. Fig. 37 shows such a template applied to an axle which needs straightening. If only one end of the axle beam has been damaged, templates may be made by fitting them to the good end, and used to check the damaged end.

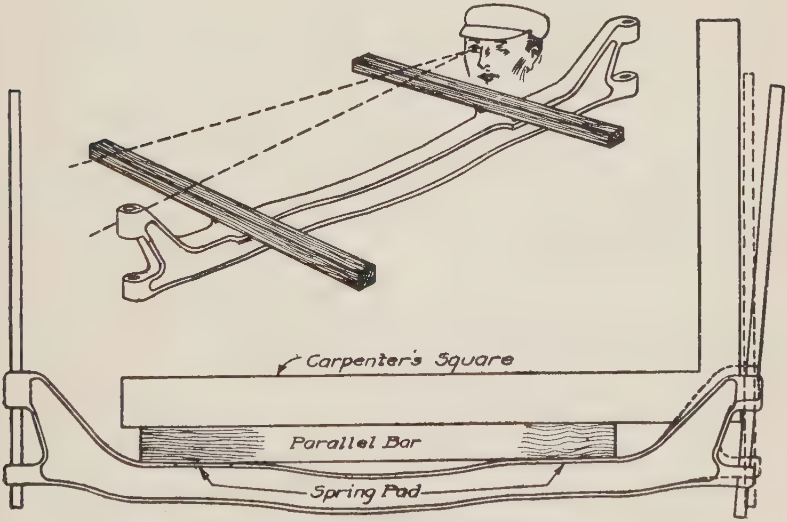


Fig. 38. Diagram Illustrating Method of Truing-Up an Axle

When the axle is straightened to its approximate original position, a pair of straightedges laid on top of the spring pads will be of great assistance in getting the springs parallel, as the worker can look across the straightedges with considerable accuracy. This is indicated in the first part of Fig. 38, which shows the general scheme. It shows also how the axle ends are aligned, using a large square on top of a parallel bar, but of course this cannot be done until the last thing, at least not until the spring pads are made parallel.

FRONT SUSPENSION—FRONT AXLE—STEERING GEARS

PART III

STEERING GEARS

The mechanisms by which steering is effected are among the most important features of a car if not actually the most important. The truth of this statement will be realized when attention is called to the fact that safe steering is the final requisite that has made the modern high speeds possible, for without safe and dependable steering gears no racing driver would dare to run a machine at a high rate of speed, knowing that at any minute the unsafe steering apparatus might shift the control, thus allowing the front wheels to waver and the car to run into some obstruction by the trackside or, even worse, to cause the wrecking of other cars.

The same argument applies in an even greater degree to the case of the non-professional driver, who wants to be on the safe side even more, perhaps, than do the dare-devils who drive racing cars. Nearly all of our roads are curved and, to make all of these turns with safety, the steering gear must be reliable. Again, in mountainous country where there may be a sheer drop at the roadside of hundreds of feet, it becomes necessary that the steering mechanism be very accurate and that it obey at once the slightest move on the driver's part. To secure this accuracy, there must be no lost motion or wear on the interrelated parts.

These things mean that the whole steering mechanism must be safe and reliable; strong and accurate; well made and carefully fitted; well cared for; and finally, the design and construction must be based on a theoretically correct principle, for otherwise the mechanical refinements will have been wasted. Perhaps it will be more logical to treat the mechanical requirements first by showing how the present type has been evolved from the failures of the earlier constructed forms.

General Requirements. In turning a corner a car follows a curve, the outer wheels obviously following curves of longer radius than do the inner wheels and therefore traveling farther. In straight-ahead running, the wheels run parallel at all times and travel the same distance. These two facts are the basic ones which make the steering action so complicated.

This double requirement leads to the usual form of steering arrangement, called, after its inventor, the "Ackerman." It was Ackerman who brought out the first vehicle in which the front wheels were mounted upon pivoted-axle ends, these ends being pivoted on the extremities of the central part of a fixed axle, while the pivoted ends carried one lever each. These levers were connected together by means of a cross-rod, while at one end another rod was attached, which was used to move the wheels. By moving this latter rod, both wheels were compelled to turn about their pivot points, since the cross-rod joined them together, and if one moved the other had to move also. This was Ackerman's substitute for the fifth wheel which had been used up to that time.

Steering Gear Front=Axle Hook=up. The student has made a study of the design of the front axle, and has an understanding of what is necessary to secure proper steering thereof. The method of hooking up the steering gear with the front axle is illustrated in Fig. 39. In this illustration the means of connecting these two units is the drag link marked *A*. The forward end of the drag link connects by means of a ball and socket joint, with the third arm, *B*, which is forged integral with the left-hand steering knuckle of the axle assembly. The rear end of the drag link connects with a ball on the lower portion of the pitman arm *C*. This pitman arm is moved in a reciprocating fashion, by the turning of the steering wheel which operates the shaft running from the steering wheel to the steering gear housing, marked *D*. This shaft is sometimes called the worm shaft inasmuch as early type gears usually incorporated a worm on the lower part of the shaft, as do many of present-day design. The outer end of the pitman arm is connected to a cross shaft, *E*, which is operated by the screw on the steering wheel shaft, through one form or another of gear or cam.

The history of steering gears takes the student through a long line of devices designed to give effective and safe steering. Some of the early gears were of the plain pinion and bevel gear type, some were of the planetary type, others were mere spur gears, and then came the adoption of the worm and gear, popular over a long period of time. Sometimes a full gear was used in this construction, and in other cases, as illustrated in Fig. 40, only a sector of a gear was used to mesh with the worm.

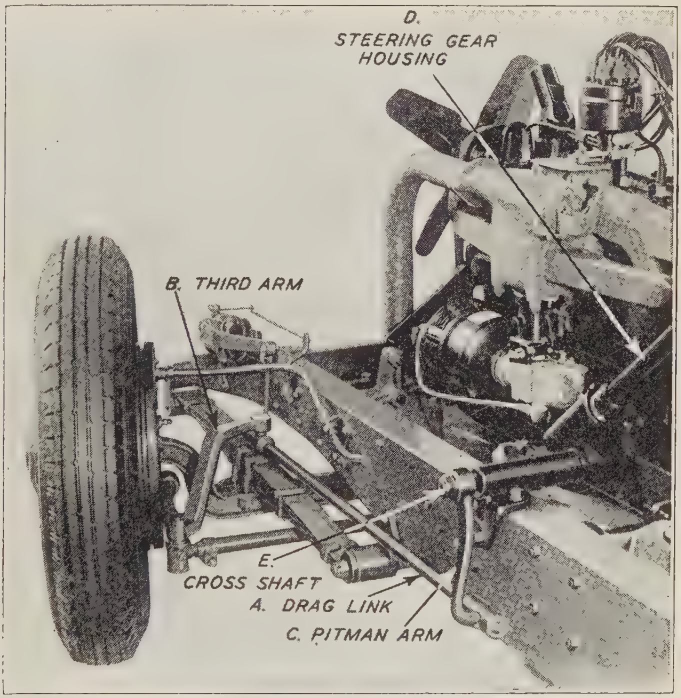


Fig. 39. Conventioned Steering Hook-Up

Worm and Gear Steering Gear. Fig. 40 illustrates this type of construction. In this view the steering gear housing is shown at *A* and the mounting flange is shown at *B*. The cross shaft which carries the pitman arm *F*, is shown at *C*. The worm is illustrated at *D* and the sector with which it engages and which operates it when the steering wheel is turned, is illustrated at *E*. The pitman arm *F* moves in a fore and aft direction and serves to operate the steering gear knuckle by means of the drag link which is shown at *A*, Fig. 39.

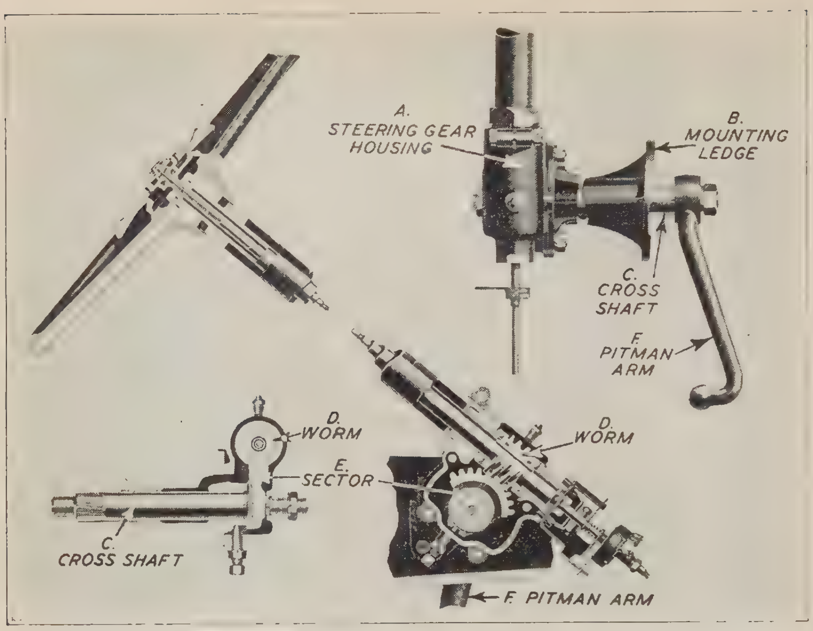


Fig. 40. Worm and Sector Steering Gear

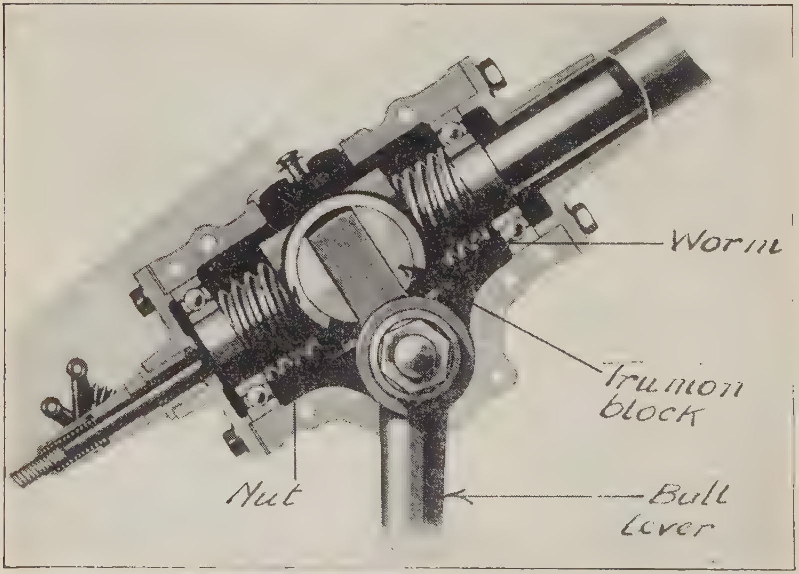


Fig. 41. Worm and Nut Steering Gear

Worm and Nut Gear. Another form of steering gear, is the worm and nut, which is made in several different combinations. Thus the nut may operate the steering lever directly through the medium of a secondary lever or it may actuate a block, which in turn moves either the lever direct or the secondary lever.

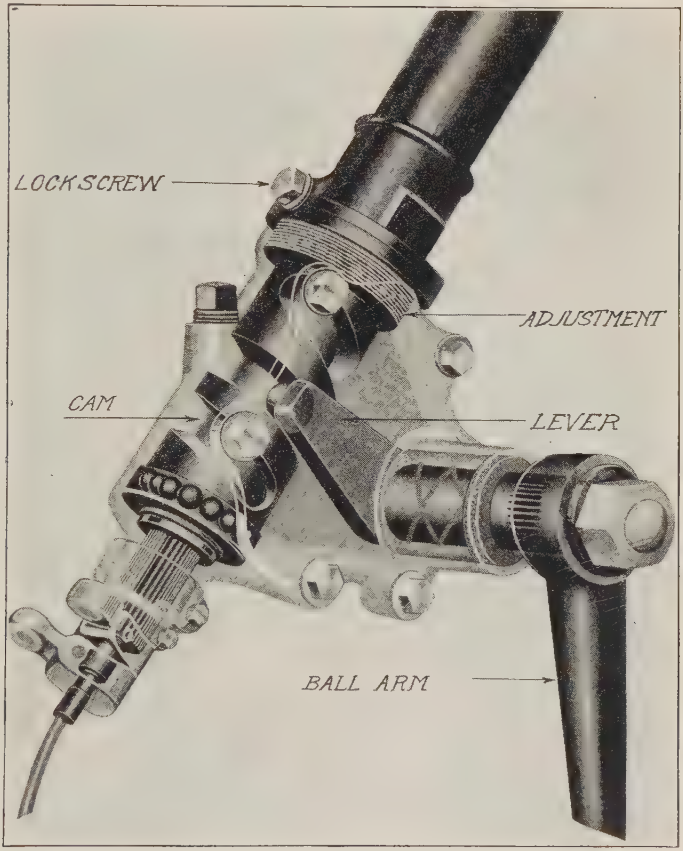


Fig. 42. Cam and Lever Steering Gear

An excellent example of the worm and nut type of steering gear is shown in Fig. 41, which is a Packard installation, used on one of the Straight-Eight models. In this steering gear, the worm moves the nut, which in turn moves the ball lever through a trunnion block which is held in a spherical seat. Attached to the ball lever are two projections which slide in the slots in the trunnion blocks.

Cam and Lever. A variation of the worm type of steering gear is found in the Ross steering gear in which a worm, called a cam, is used to move a lever, Fig. 42. The worm or cam member is very similar to a single thread with variable pitch and is assembled between ball bearings which take both thrust and load. As the steering wheel is moved, the projection on the inside of the lever moves in the worm or cam, up or down, and the steering lever is moved. The lever is attached to the shaft by a spline. The variable cam has the advantage for as the wheel is turned the movement of the lever becomes more rapid at a greater turning angle. The variable pitch gives slow action at the straight-away position and practically eliminates the road shocks and gives the desired irreversible quality needed in steering gears.

An adjustment for lost motion with up and down play is allowed by the introduction of shims under the thrust nut. In order to take up this lost motion, the lock screw should be loosened and the thrust nut backed off and one of the shims should be split and removed. This should be repeated until all lost motion has been removed. However, the adjustment should not be such that the steering gear turns hard or it will tend to strain the steering and most likely cause the balls in the bearings to break. For lubrication purposes, the steering gear housing should be filled with a heavy liquid grease, such as 600 W.

CADILLAC STEERING GEAR

Fig. 43 illustrates the type of steering gear utilized on the larger Cadillac cars, and shows the right-hand side of the automobile. This design incorporates two universal joints between the steering shaft and the worm shaft of the steering gear. These joints tend to prevent vibration and road shock from being transmitted to the car body through the steering shaft and also tend to reduce road shock or steering wheel whip being transmitted to the steering wheel. The Cadillac automobile also makes use of needle bearings in the steering knuckle pins to reduce the steering friction and make handling of the car easier.

The worm in the steering gears is of the conventional hour-glass type. It operates the sector through a double-tooth roller carried on two rows of ball bearings with the bearing cones clamped in the forward end of the sector by means of the roller bolt. The bearings are universal, taking both the radial and thrust loads. The worm is mounted between two tapered roller bearings. Roller bearings are also used on the sector shaft.

Worm and Roller Type Gear. The worm and roller type of steering gear is illustrated in part section view in Fig. 44, where it will be noted that the worm is of the hour-glass type. That is, the worm is not of uniform diameter, the central portion being smaller than the ends. The general contour of the worm is on a radius with the center line of the cross shaft. This form allows the roller, which is carried within the yoke which takes the place of the gear or gear sector, to swing in the arc formed by the worm. The roller within the yoke is carried between the ball or roller bearings, and maintains close contact with the sides of the screw threads at all times. This type of design makes for exceptionally easy steering, inasmuch as all loads are carried by ball or roller bearings. In effect, the design gives a single tooth gear being moved in an arc by means of the hour glass type of worm.

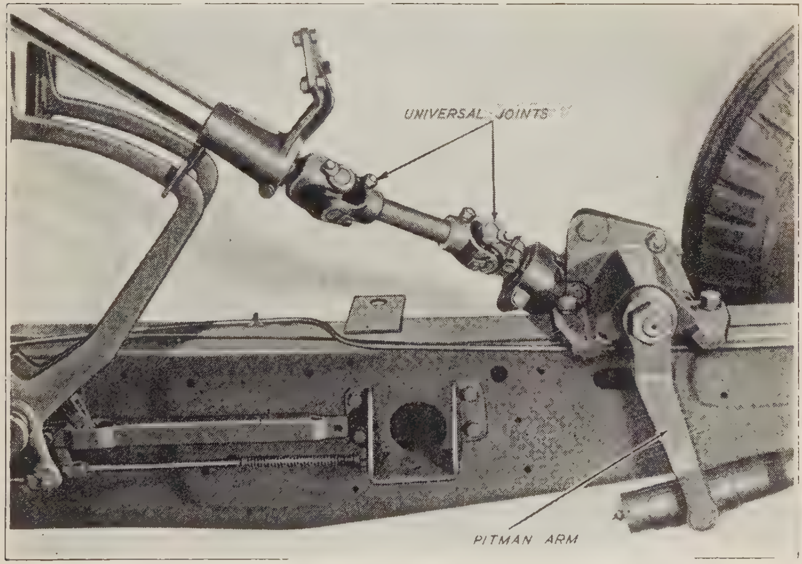


Fig. 43. Cadillac Steering Gear Equipped with Two Universal Joints
Courtesy of Cadillac Motor Car Company

Worm and Three-Tooth Sector Steering Gear. Fig. 45 illustrates in sectioned view, a steering gear column having the worm carried on the lower end of the worm shaft, this worm being shown in full section in contact with a sectioned view of a three-tooth sector gear. In this design also, the hour glass type of worm is used.

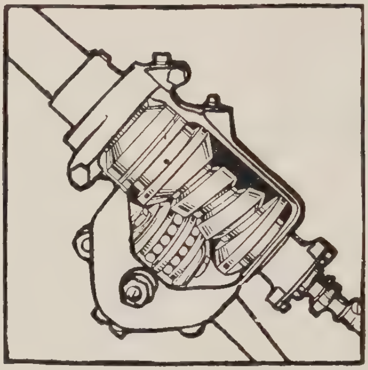


Fig 44 Worm and Roller

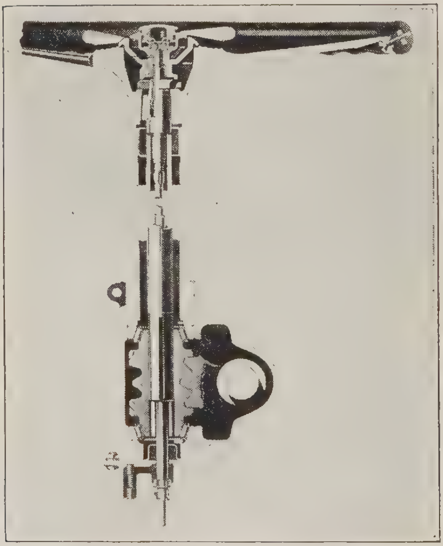


Fig. 45. Worm and Three-Tooth Sector

The three-tooth sector is caused to swing on the cross shaft in an arc which is approximately the same as the arc on which the worm is cut. There is a slight difference in the arc, so that as the sector is thrown from end to end on the worm, there is slightly more clearance in the endmost position. Inasmuch as this is not a critical steering point, the extra play does no harm. The critical steering point in all steering gears, is central or straight ahead position, and at that point the most wear occurs. By allowing slightly more play at the ends than in the central part of the worm and sector contact, longer life is assured.

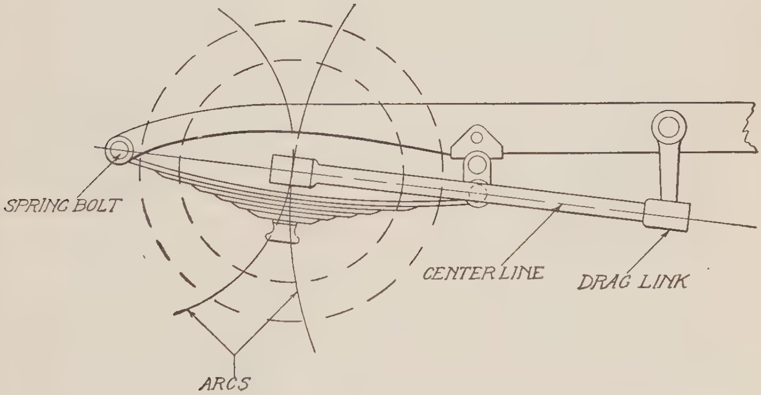


Fig. 46. Correct Drag Link Position

Drag Link. Figs. 39 and 46 illustrate drag links. Fig. 46 illustrates the position the drag link should assume for conventional front spring mounting, with the spring bolt at the forward end of the car frame, rather than at the rear end of the front spring. The position of the drag link will be noted as having the pitman arm in a vertical position, with the forward end of the drag link centrally disposed over the front axle.

Under load, the forward end of the drag link in this design, moves in an arc which coincides at point of contact with an arc described by the front ends of the front spring. If the drag link is not in the position shown in Fig. 46, under normal load, it will be found that steering is erratic. This is explained to a further degree in a later paragraph.

The construction of most drag links is quite similar to the ones illustrated in Figs. 47 and 48. Fig. 48 shows the assembled views of the ball in dotted line, while Fig. 47 illustrates the steering-arm end of a drag link in sectioned view. Here it will be noted that a tubular member is used for the drag link, containing within it a flat washer and a plug, which are contacted by a spring. This spring is contacted by the rear ball seat. Next to that is the ball, and holding the ball in position is another ball seat in the form of a nut which is screwed into threads within the large end of the drag link. After these parts are assembled, the nut is locked into the link by means of a cotter key, which is shown in the slot of the drag-link nut. When assembling the nut and other parts of the drag link, be certain they are in proper order, and that the nut is screwed in until it is tight. After this, back the nut off one-half turn and install the cotter key for safety.

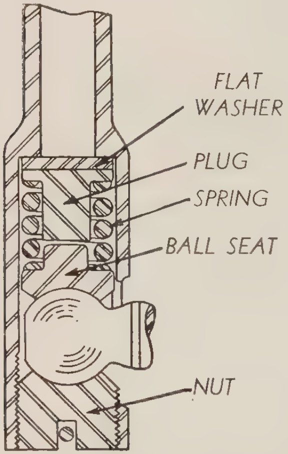


Fig. 47. Sectioned View of Steering-Arm End of a Drag Link

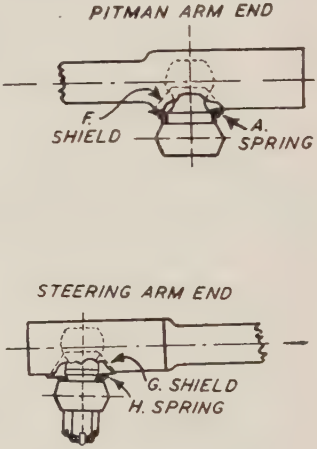


Fig. 48. Views of Ends of Drag-Link Assemblies

In Fig. 48, *A* indicates a spring which is fitted down over the ball stud on the pitman arm end, and *F* indicates the shield cup on the top of the spring. If the ball stud has been removed from the steering arm, the shield *G* must be put over the shank of the ball stud, and the spring *H* next to the shield, since the dust shield will not pass over the ball stud. These parts are provided to prevent dust entering the joint of the ball and socket arrangement, which is used to give a universal motion. They also serve to hold in the lubricant supplied.

Tie Rod. Fig. 49 illustrates a front system of a conventional type, with the tie rod indicated by an arrow. The tie rod serves the purpose of maintaining the front wheels in proper alignment, as explained in Part 2 on front axles. Adjustment of the tie rod is required in order to maintain the front wheels with proper toe-in. This is the distance, as explained previously, between the lines *A* and *B*, as shown in Fig. 49. The method of obtaining this distance in the correct amount is by means of measuring with the front wheel tramming device shown in the lower part of Fig. 49. Adjustment is usually made by loosening the adjusting end clamps and turning the tie rod which is provided with both right- and left-hand threads, thus throwing the wheels closer at the rear or farther apart at that point. Fig. 50 illustrates an Oldsmobile type of tie-rod end joint for independent wheel suspension center steering. Owing to the motion of the tie rod in relation to other front axle parts, it is necessary to have a special type of joint provided. Sometimes this

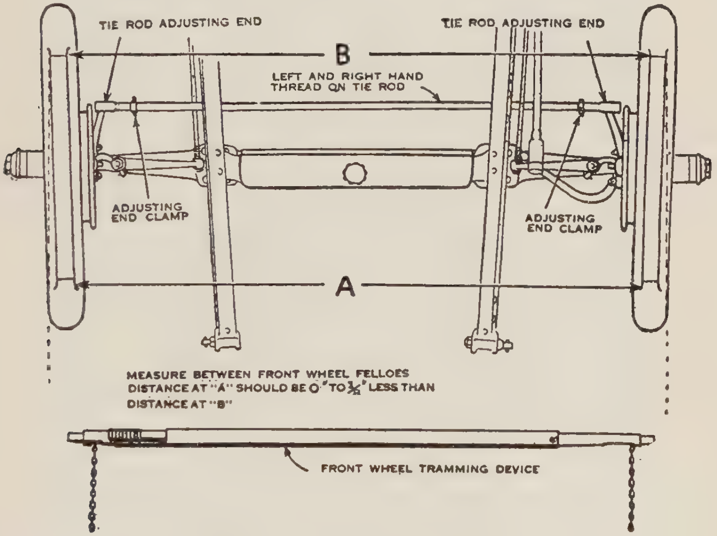

TIE ROD ADJUSTING END
TIE ROD ADJUSTING END
B
LEFT AND RIGHT HAND THREAD ON TIE ROD
ADJUSTING END CLAMP
ADJUSTING END CLAMP
A
MEASURE BETWEEN FRONT WHEEL FELLOES DISTANCE AT "A" SHOULD BE 0" TO 1/8" LESS THAN DISTANCE AT "B"
FRONT WHEEL TRAMMING DEVICE

Fig. 49. Measuring for Gather or Toe-in

takes the form of a ball and socket joint. In other cases the joint illustrated is used. This particular tie-rod end is provided with self adjustment, and the bearing, which is used for supporting the stud, is of a spherical design. The two parts are maintained in contact with one another by means of a tension spring which is located beneath the ball seat, which in turn is forced into contact with the ball within the tie rod end. The bolt is fitted to the tie rod with the fitting shown in the lower left-hand view, Fig. 50, and the long taper on the bolt is used for fastening it to the steering-arm end of the steering knuckle. A spring under the arm end is thrust downward and forces the dust pad in close contact with the other parts of the tie-rod ends, thus preventing lubricant from being lost, and dust from entering.

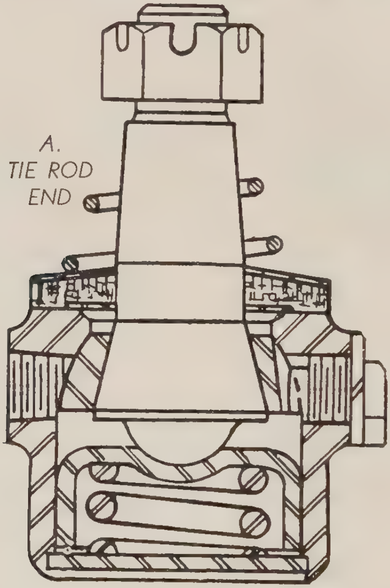


Fig. 50. Tie-Rod End

Steering-Gear Kick Shackle. In order to overcome the tendency of a front-wheel assembly to shimmy under certain conditions, kick shackles similar to that illustrated in Fig. 51 were introduced and used on many automobiles. Usually the principle incorporated a certain spring or rubber-mounted device at the forward end of the spring which was shackled at the forward end. The springs

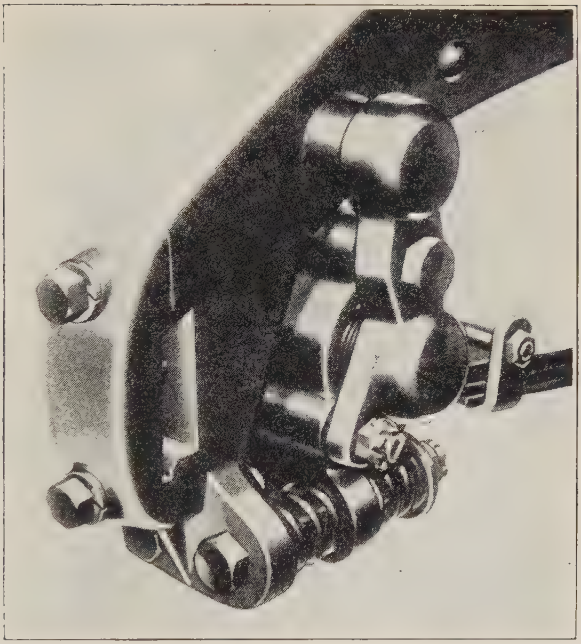


Fig. 51. Kick Shackle

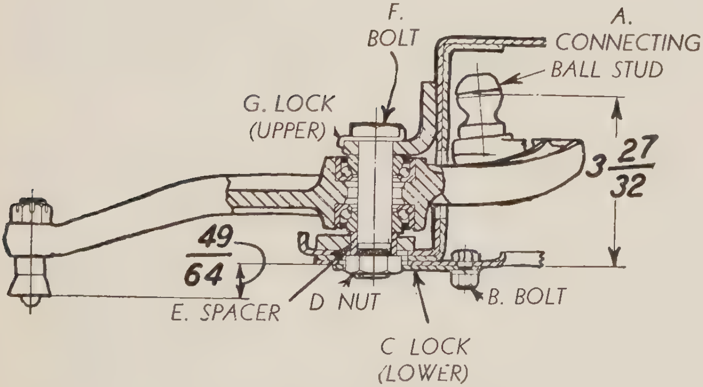


Fig. 52. Buick Intermediate Steering Arm

allowed for a certain amount of motion at that point, without transmitting the shock to the car frame and setting up a shimmying action of the front wheels. The effect of the road shock being absorbed in the shackle also prevents the transmission of road shock to the steering wheel, and the natural reaction which follows such shock transmission, the conditions ordinarily known as tramp and shimmy.

Center Steering. Figs. 12, 13 and 14 of the front suspension section, Part 1, illustrate the front ends with independent wheel suspension and having center steering. It will be noted that in each case two short tie rods are used instead of one long tie rod. In the case of the Plymouth car, Fig. 13, cross steering is used, the steering drag link, however, being shown in a centrally disposed position instead of cross disposed, as is its normal position. When center steering is used with the drag link being run along the car frame fore and aft, it is necessary to utilize an intermediate steering arm as illustrated in Fig. 52, this being the Buick "40" model. It will be noted that this steering arm is mounted on two ball bearings

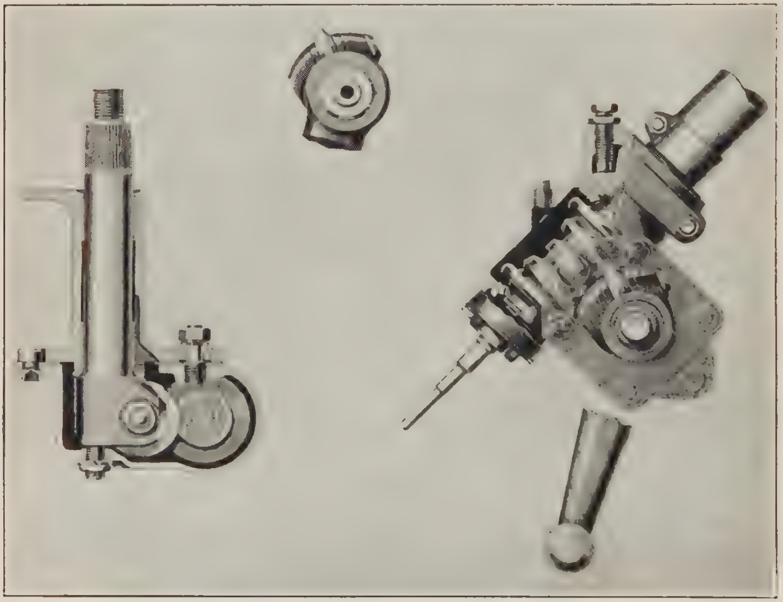


Fig. 53. The Gemmer Worm and Roller Steering Gear

and is supported in a bracket fastened to the front cross member. The bearing and arm hub are packed full of grease at assembling. The intermediate arm bearings are set up with a free load of one to two pounds when measured with a spring scale fastened to the steering connecting ball stud *A*, Fig. 52, this load to be measured with the steering connecting and tie rods, disconnected from the arm. At no time should this load exceed two pounds maximum. In order to adjust these bearings, first remove the bolt *B* and the lock *C*, after which tighten the nut *D* against the spacer *E* until the desired free load is obtained on the arm bearing. The bolt *F* should be held while tightening, to prevent the upper lock *G* from being damaged, after which reinstall the lower lock *C* and the bolt *D*. The steering connecting-rod ball and tie-rod ball locations should check with the dimensions *H* and *I*, Fig. 52, within 1/16 inch. These measurements are taken from the lower surfaces of the front cross member.

GEMMER STEERING GEARS

While some of the earlier models of the Gemmer steering gears are still in use on a number of cars, later models make use of the worm and sector and worm and roller steering gears. These gears have been adopted on a wide range of cars. Certain models of the Chrysler, Ford, Jordan, Nash, Dodge, Graham-Paige, Stutz, Essex, Hudson, Black Hawk, and Pierce-Arrow are equipped at the factory with the Gemmer gears. The auto-mechanic will quickly learn to recognize cars equipped with these gears, which are easily serviced. The gears, Fig. 53, can be adjusted without removing them from the cars. The adjustments are the same for the two types, and the instructions that follow, which are prepared specifically for the worm and sector type, are equally adaptable to the worm and roller type. Except for the substitution of a roller for the sector, there is no constructional difference. A wrench and screwdriver will serve to do the job of adjusting. Ordinarily, the lighter cars make use of the sector type of steering gear, while the heavier and high-price cars make use of the roller assembly.

Adjusting Gemmer Worm and Sector Steering Gears. Means of mechanically eliminating all play within the mechanism have been provided by the gear manufacturers. There is no need of being forced to choose between a stiffly operating unit and one having lost motion, since none of the adjustments are indexed but all can be set at the will of the adjuster at the most desirable point.

The front wheels of the car should be jacked up and the drag link removed from steering-gear ball arm in order to effect a satisfactory adjustment of the steering mechanism. Loosen the car-frame bracket bolts and turn the steering wheel from one extreme position to the other extreme position to correct any misalignment that may exist between the various supports. Tighten these bolts very securely when the parts are realigned. Loosen the instrument board steering-gear bracket and column. The column must not be

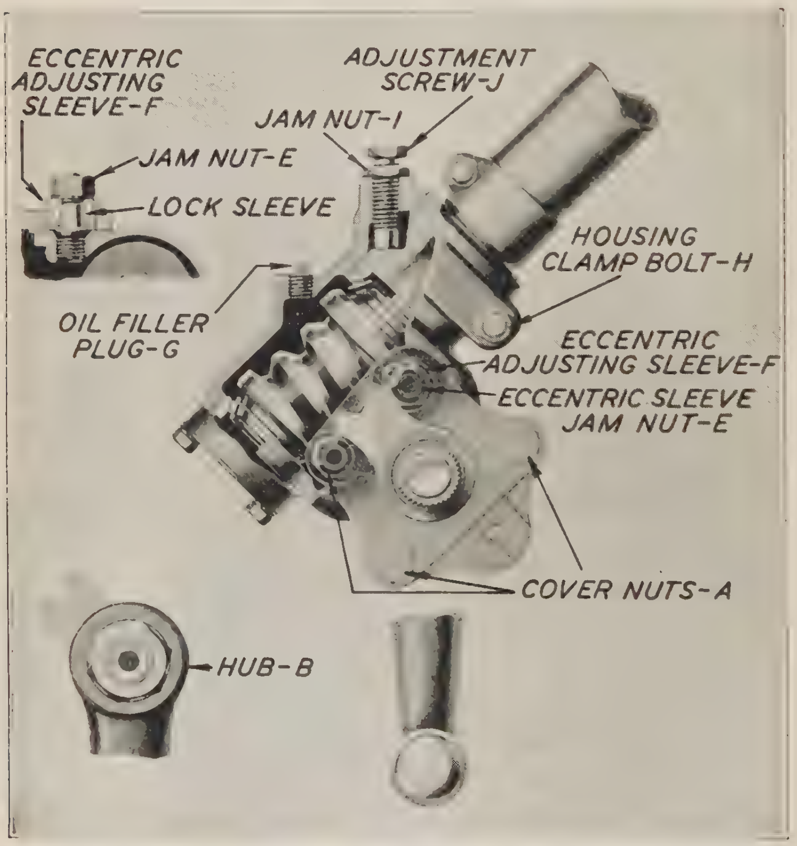


Fig. 54. Adjustments for Column End Play and Sector Tooth Mesh of Gemmer Gear

sprung in any direction. If it is, check for and remove the source of misalignment.

Adjustment of End Play in Cross Shaft. See that the housing cover nuts *A*, Fig. 54, are tightened securely. Turn the hand wheel to either extreme and back an eighth of turn. Gripping the ball arm at the hub *B*, the shaft should rotate freely without a particle of end play. Adjust the end play as required by means of the adjusting screw *C*, Fig. 55, at the side of the housing next to the engine. Be sure to lock the screw securely with the lock nut *D* and reinspect for end play and freedom.

Adjustment for End Play in Column. To adjust for end play in the column or between the worm and roller bearing thrusts, turn the steering wheel to either end stop and back up one-eighth turn or to a point where there is lash of the ball arm. This leaves the column bearings free of side thrust. Loosen the housing clamp bolt *H*, Fig. 54, and the jam nut *I* on the housing sleeve adjusting screw *J*. Turn down the adjustment screw as tightly as is possible with a six-inch wrench and then back off one-sixth turn. Set the jam nut and the housing clamp bolt securely. Turn the hand wheel from extreme to extreme positions and test for stiffness or high spots.

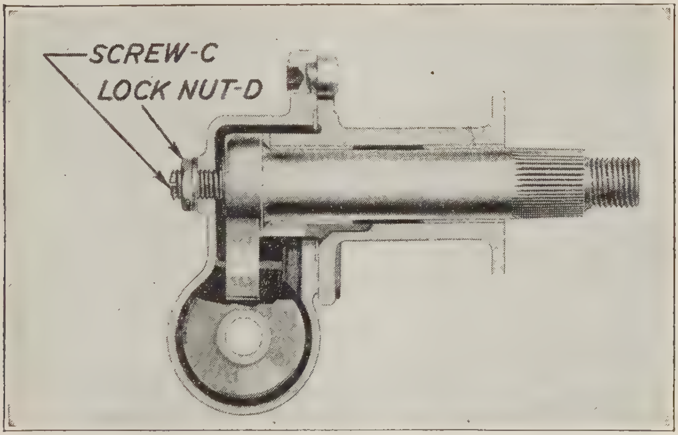


Fig. 55. Adjusting End Play on Cross Shaft of Gemmer Gear

Adjustment for Proper Mesh of Sector Teeth in Worm. Turn the hand wheel to the mid-position of its complete travel or turning limits. Have the drag link previously disconnected. The handwheel keyway should now point straight upward toward the roof of the car. Correct it to this condition by the shortest movement. Most wheels are marked underneath the spoke that corresponds to the keyway position, by a large trade mark or depression. Shake the ball arm to determine the amount of lost motion. Loosen the housing cover nuts *A*, Fig. 54, one-fourth turn and the eccentric sleeve jam nut *E* one-half turn. Turn the eccentric adjusting sleeve *F* clockwise very gradually, checking at each movement the amount of lost motion still existing at the ball arm. Adjust only sufficiently tight to eliminate all lash of the ball arm and no more, being sure to finish the movement of the eccentric adjusting sleeve *F* in a clockwise direction. Turn the hand wheel throughout the full travel to test for free operation. If too tight, turn the eccentric adjusting sleeve *F* counterclockwise to free it, and readjust as above more carefully. Tighten the eccentric adjusting sleeve jam nut *E* securely first and follow likewise with housing cover nuts *A*. This is very important.

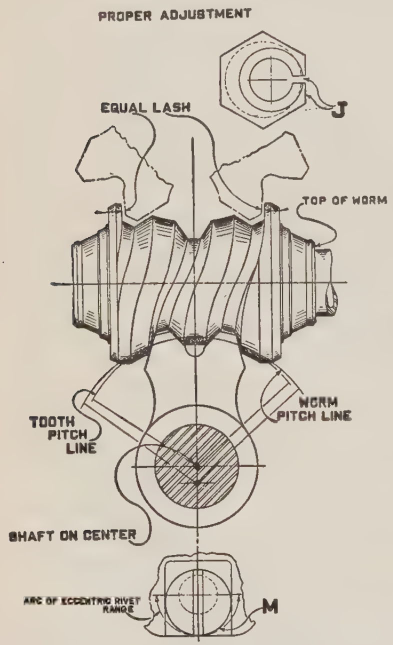


Fig. 56. Pitch Lines of the Gemmer Gear Worm and Tooth

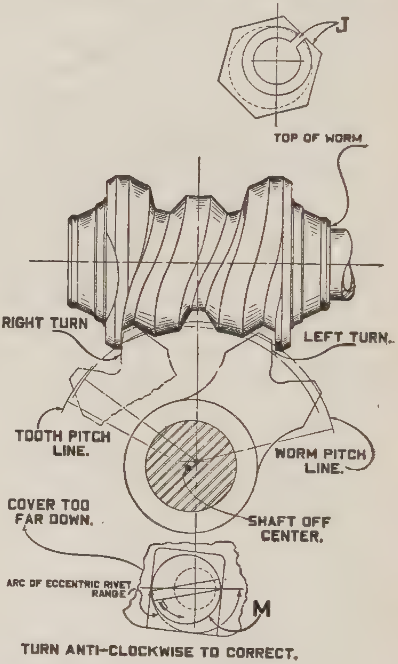


Fig. 57. Cross Shaft Center too Low

The foregoing adjustments will suffice in nearly every instance. For cases where there is evidence of improper centralization of tooth contact, the following description and instructions are outlined.

Centralizing Tooth Contact. The pitch radius of the worm is longer than the radius of the arc described by the sector teeth, Fig. 56. This provides for the closer mesh of these parts at the mid-position of the full movement of the sector shaft. It is essential, however, that the pivotal point of the shaft pitch radius is located on the same line as is the pivotal point of the worm pitch radius and which line is at a right angle to the worm center line to insure against the possibility of closer mesh away from the mid-position and poor contact of tooth face to worm track. To obviate the incorrect conditions brought about through improper adjustment or slight inaccuracies in factory production, correction through the medium of the eccentric rivet *M* is provided. Turning the eccentric rivet in either direction shifts the sector tooth shaft pivotal point likewise toward or away from true alignment with the pivotal point of the worm pitch radius.

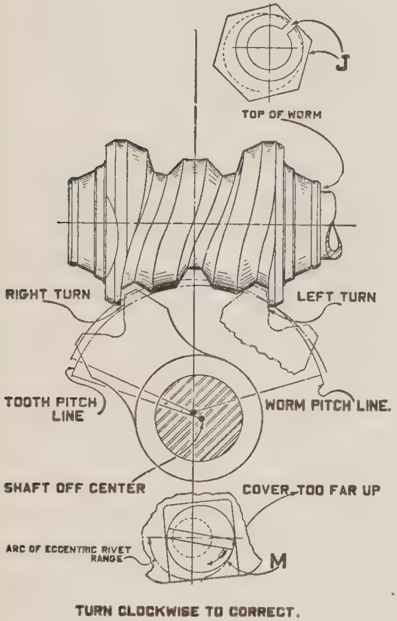


Fig. 58. Cross Shaft Center too High

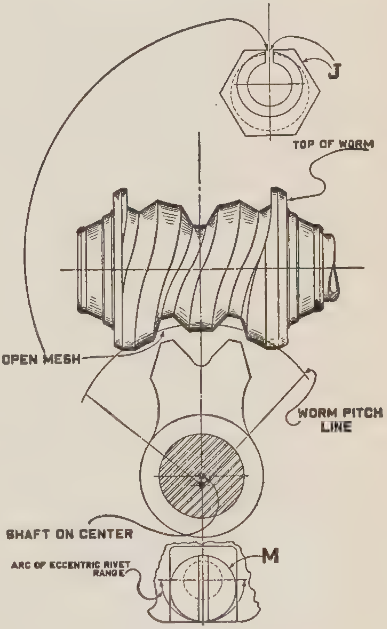


Fig. 59. Cross Shaft Center on Center with Worm Center

Figs. 57 and 58 illustrate the extreme conditions brought about by misalignment of the shaft and the worm pitch radius pivotal points. Fig. 58 shows the shaft pivotal point being too far toward the upper end of the housing, making for closest mesh at the left-hand extreme throw of the steering wheel and for abnormal lash at the right-hand extreme throw. Fig. 57 shows the same error in the opposite direction.

These conditions are easily diagnosed by comparing the amount of lash at two positions an equal distance each side of the mid-position, this distance being determined by the point of least lash farthest from mid-position. Mid-position is located by keyway position as previously described.

To overcome the condition illustrated in Fig. 58, turn the eccentric rivet clockwise, which moves the shaft pivotal point toward the lower end of the housing, until the measured lash at the points are equal. Alter the mesh adjustment to suit this new shaft pivotal point location. To remedy the condition illustrated in Fig. 57, turn the eccentric rivet counterclockwise, which moves the shaft pivotal point toward the upper end of the housing. The effective range of the eccentric rivet prevails throughout the arc illustrated. Its highest point may be situated at any position within this arc as influenced by the correct adjustment needs.

Figs. 56 and 59 illustrate the proper pivotal point location, both shaft and worm pitch radius pivotal points being on the line which is at right angles to the worm centerline. Fig. 59 shows the open mesh of the sector tooth and worm and Fig. 56 shows the closed mesh at mid-position with equal lash at the points and equal distance from the mid-position, which is proper alignment and adjustment for the shaft center position.

At the top of Figs. 56, 57, 58, and 59, the eccentric sleeve for mesh adjustment *J* is shown at relatively the positions bringing about open and closed meshes, respectively. If these adjustment instructions are followed carefully, proper functioning of the steering mechanism will result. Do not deviate from these instructions to correct any erratic action of the front wheels as evidenced by shimmy or steering wheel fight, but instead see that the tires are properly inflated and the front axle checked for correct toe-in, camber, and caster specifications. Shock absorber tension or adjustment should be at the recommended standard. Tie rod and drag link sockets or connections must also be adjusted to correct tension and freedom.

Lubrication. Remove the pipe plug *G*, Fig. 54, in the steering gear housing or attach the filler device to the nipple and fill with approved lubricant until it overflows through the vent in the jacket tube just above the adjusting nut. Avoid the use of graphite, white lead, or heavy solidified oil or grease.

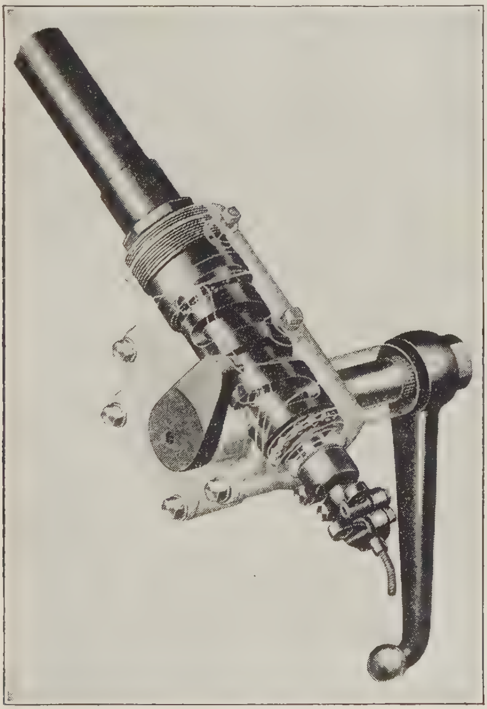


Fig. 60. Ross Cam and Lever Steering Gear with Sliding Stud Contact

ROSS CAM AND LEVER STEERING GEAR

There are two models of the Ross cam and lever steering gear. This gear came on the market about the time balloon tires and front-wheel brakes combined to complicate the steering-gear problem.

Cam and Lever Steering Gear with Sliding Stud Contact. The earlier model of this gear is illustrated in Fig. 60, which shows a phantom view of the screw or worm which is an integral part of the lower or stud shaft. Fig. 61 illustrates one of these gears which has been completely disassembled.

The thrust on the Ross screw, which is termed a cam, is taken up by the two ball bearings—one above and one below the cam section. A study of Fig. 61 will show that the pitch of the screw or cam is greater nearer the ends of the cam than at its center. This can be more readily seen in Fig. 62. Because of this, steering is speeded after the wheels are cramped off the center line, as in rounding a sharp turn; while when in the straight ahead drive position, a great deal of power is available for steering so that a very light touch does the work required to keep the car on the road.

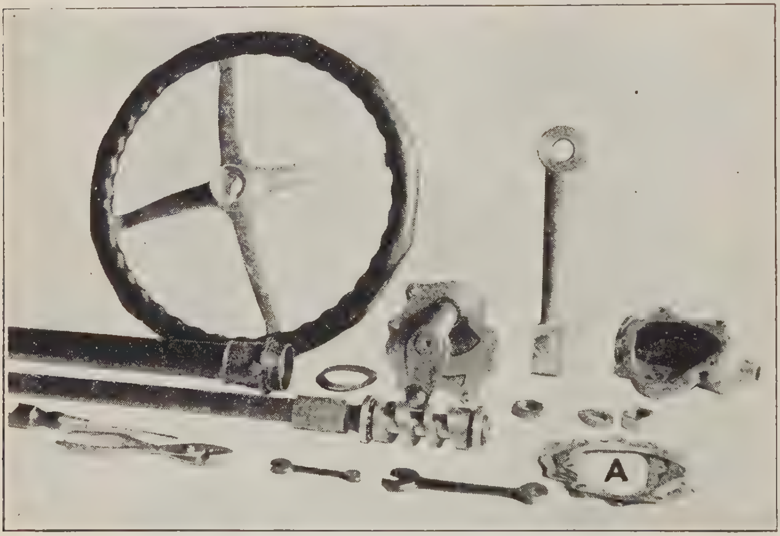


Fig. 61. Ross Sliding Stud Contact Cam and Lever Steering Gear

Roller Mounted Cam and Lever Steering Gear. This gear, Fig. 62, is almost identical with the one shown in Fig. 60. The chief difference is in the pitch of the screw on the cam, which is somewhat slower, and in the mounting on the lever stud. In the older model the lever stud was part of the lever so that a sliding action resulted between the parts when the gear was turned. The rolling action of the roller mounted lever stud provides fifty per cent easier steering.

Adjusting Cam and Lever Steering Gear. In Fig. 61 it will be noted that the cover plate is assembled on the gear box, having a number of shims *A* which are used for adjustment. When wear has occurred between the lever stud and the cam thread, a thin shim is removed and this allows the tapered stud to mesh deeper with the cam thread, thereby eliminating cam play. The adjustment for up and down play of the steering gear cam is taken up by means of the threaded collar and nut arrangement at the upper end of the gear case. Adjust this until no play is felt, after which back it off one-sixth turn to allow a free movement.

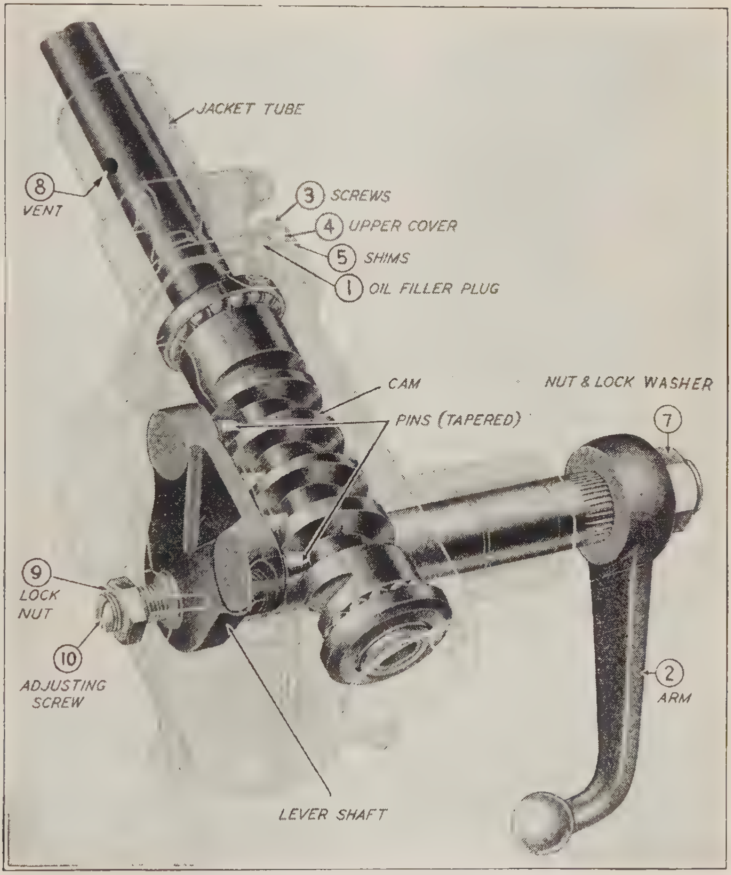


Fig. 62. **Ross Cam and Lever Steering Gear with Twin Pins**
Courtesy of Ross Gear and Tool Company

When adjusting the shims to take up the lever stud and cam thread play, **be sure not to remove all backlash.** Remove just enough shims to allow for a very slight backlash and test the gear from one end of the cam thread to the other, that is, through its entire range of movement, for high spots.

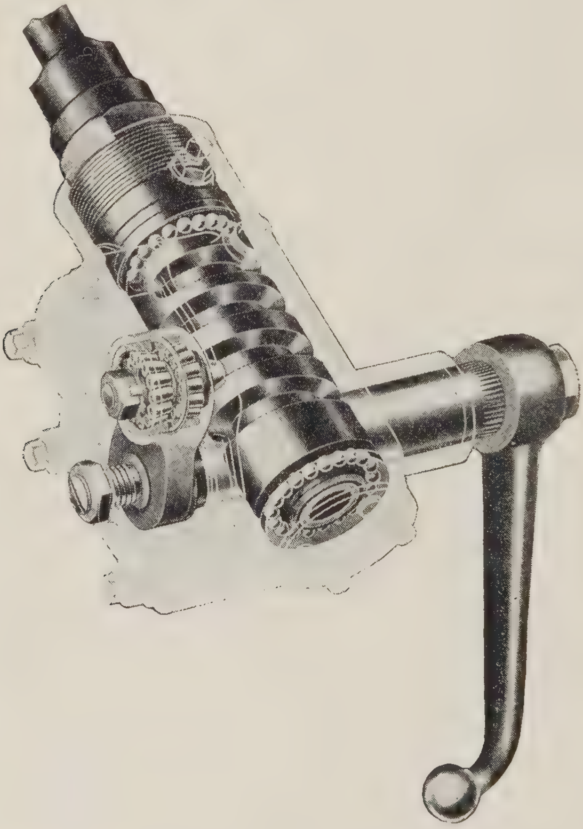


Fig. 63. Ross Roller Mounted Cam and Lever Steering Gear with Rolling Stud Contact

Up and down play on the roller mounted cam is taken care of by means of an adjustment at the upper end of the steering-gear case. Play between the roller stud and the cam screw is removed by adjusting the thrust screw on the inner end of the cross shaft, as shown in Fig. 63. Loosen the lock nut and then turn up the screw until no play is felt, after which the screw should be backed off slightly to allow freedom of movement, and the action tested throughout the range of motion for high spots.

ROSS CAM AND TWIN LEVER STEERING GEAR

Fig. 62 illustrates the constructional features of the newest cam and lever steering gear manufactured by Ross Gear and Tool Company. This gear set operates on the same principle as the single pin and the roller bearing mounted stud gears, except where the introduction of the two pins, which are designed to operate in such manner as to give effective steering with slight steering effort, afford certain advantages. The gear set is designed with the grooves in the cam cut shallower in the straight-ahead driving position. The taper grooves at other points, than the straight-ahead, allow more clearance for the pins with freer action. It also permits of compensating for wear by adjusting the pins into the groove without having the pins come tight at other points after such wear has occurred on the high range or straight-ahead position. The sides of the grooves are on a uniform angle designed to fit against the pin taper in any position. Thus, it will be seen that varying the depth of the groove makes for what might be termed a high range or support at those points where the groove is shallower. In this manner a very sensitive adjustment is permissible. This particular feature of design must be held in mind in making any adjustment on the gear set. The order of servicing the gear, including adjustment, is given in the following paragraphs.

Lubrication is through the pipe plug hole. Fill the housing slowly with steering gear lubricant until it begins to run out of vent hole, *8*. Do not use ordinary grease. Repeat the operation every 5000 miles or more often if necessary.

When preparing to make adjustments, first free the steering gear of all load, preferably by disconnecting the drag link from the steering arm. Next, loosen the instrument board bracket clamp on the steering gear jacket tube.

The first adjustment is to take up the end play of the cam ball thrust bearings. However, before making this adjustment, loosen the housing side cover adjusting screw lock nut, *9*, and the adjusting screw, *10*, to free the pins in the cam groove. Adjust the screw to a barely perceptible drag so that the steering wheel can be turned freely with the thumb and forefinger lightly gripping the rim.

Next, unscrew the four clamp screws, *3*, and move up the housing upper cover, *4*, as far as possible—about ¼ inch—to permit removal of shims which are in a combination of .003, .010, and .030-inch shims used in between paper gaskets. Clip and remove a .003-inch shim or more as required. Reassemble the clamp screws and tighten. Draw the screws down tight. Test the adjustment with thumb and forefinger on the rim of the wheel for a free turn and if necessary remove or replace shims until the adjustment is correct.

The second adjustment is for proper mesh of the lever shaft pins in the cam groove. The backlash of the pins in the groove shows up as end play of the lever shaft, also as backlash at the steering wheel and at the ball on the arm. Remember that the groove is purposely cut shallower in the straight-ahead driving position of each pin. This produces a high range in the groove, equal at each pin, that causes closer mesh of the pins in the groove through the mid-position of travel of each pin. This feature permits a close adjustment for normal straight-ahead driving and also permits take-up of backlash at this point, after normal wear of the groove, without causing a bind elsewhere.

Adjust with the high range through the mid-position of pin travel. Do not adjust in positions off straight-ahead. Backlash at those turn positions is not objectionable. Tighten the side cover adjusting screw, *10*, until a very slight drag is felt through the mid-position high range when turning the steering wheel slowly from one extreme to the other. It must be remembered that the gear must not bind any place. Only a very slight drag should be felt. A closer adjustment will not correct any steering condition, but will serve only to damage and wear the parts and impair operation. When the proper adjustment has been made, tighten the lock nut, *9*, and then give the gear a final test. Make sure the steering gear ball arm, *2*, is tight on the splined shaft and that the lock-washer and nut, *7*, are tight also.

The final adjustment step is the column alignment. Tighten the instrument board bracket clamp on the column. Turn the steering wheel to see if any stiffness exists. If so, the gear has been adjusted too tight or the steering column is out of alignment. The steering column must not be sprung in any direction. If misalignment exists, correct according to the methods provided by the car manufacturer. Before reconnecting the steering gear connection with the front wheels, turn the steering wheel as far to the right as possible and mark the position of the steering wheel rim in line with some one point. Next, rotate the wheel in the opposite direction as far as possible and note the total number of turns as the mark passes the point. Then turn the wheel back exactly one-half of this total movement, thus placing the gear in the mid-position. Place the front wheels in position for straight-ahead driving. It should then be possible to connect the drag-link to the ball on the end of the steering gear arm without moving the gear to any appreciable extent. If this cannot be done, remove the arm from the steering gear lever shaft and place it on the splined shaft in the proper position. Otherwise it will not permit the front wheels to swing equally to the left and right, and straight-ahead driving will not be as exact and labor free.

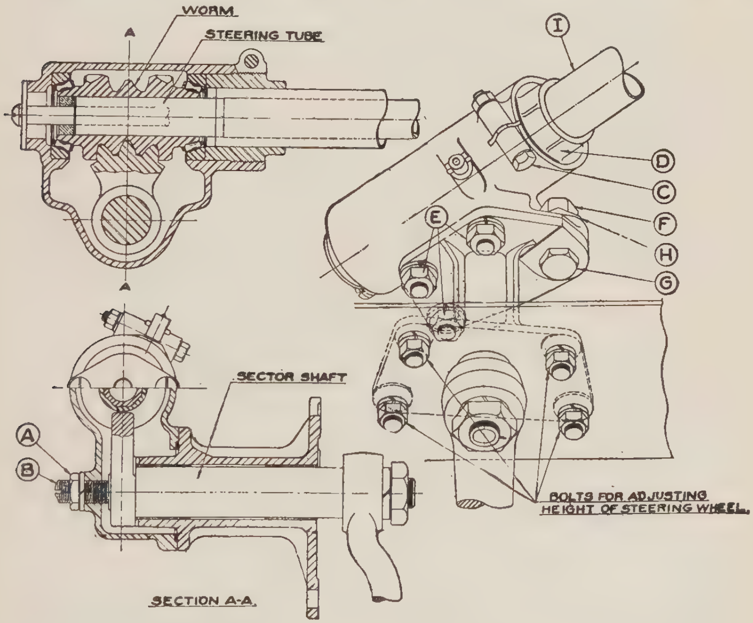


Fig. 64. Saginaw Roller Bearing Worm and Three-Tooth Sector Type Steering Gear

SAGINAW ROLLER-BEARING STEERING GEAR

Adjusting Sector Type Steering Gear. The steering gear has three adjustments: end play in sector shaft, end play in worm shaft, and backlash between the worm and sector.

To Remove Sector Shaft End Play. Loosen the nut *A* at the engine side of the gear, Fig. 64. Turn the screw *B* right hand sufficiently to remove the end play from the sector shaft and then tighten the lock nut *A* securely.

To Remove Worm Shaft End Play. Loosen the housing bolt *C*, Fig. 64, one-half turn, and where the column jacket *I* is clamped to the instrument board, loosen to allow adjusting nut *D* to be turned. Screw the adjusting nut *D* down as far as possible without stiffening the action of the steering wheel while turning through its entire range. Use care when doing this to turn the adjusting nut *D* downward, as it must be in positive contact with the bearing when the adjustment is completed. The clamp bolt *C* and the clamp at the instrument board should then be tightened securely.

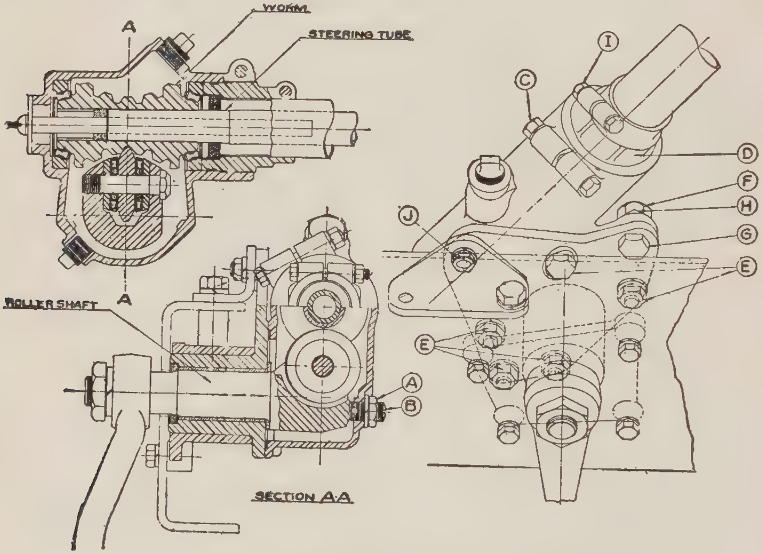


Fig. 65. Saginaw Worm and Roller Steering Gear

To Remove Backlash between Worm and Sector. Locate the wheels exactly in straight-ahead position. This is very important. Disconnect the drag link from the pitman arm and move the arm fore and aft to determine the amount of backlash. Loosen the cover stud nuts *E* one-fourth turn only. Next, loosen the nut *F* one-half turn only. With one wrench on the eccentric bolt *G* and one on the eccentric sleeve *H*, turn *G* in the clockwise direction and

H in the opposite direction in gradual stages, noting the result by moving the pitman arm at each step and using care at the last stage to turn *G* and *H* just sufficiently to remove the backlash and no farther. If *G* and *H* are turned more than is necessary, damage to the gear will be the result. In most cases one-eighth turn of the eccentrics *G* and *H* should be sufficient. Now tighten nuts *E* and *F* securely and connect the drag link. Check the backlash at the handwheel. In straight-ahead position, the wheel should not be tight but should have no backlash. When properly adjusted, the gear will be without backlash in the **straight-ahead position only.**

Adjusting Worm and Roller Type Steering Gear. This steering gear has three adjustments: end play in the roller shaft, end play in the worm shaft, and backlash between the worm and roller.

To Remove Roller Shaft End Play. Loosen the nut *A*, Fig. 65, at the engine side of the gear. Turn the screw *B* to the right sufficiently to remove the end play from the roller shaft. Then tighten the lock nut *A* securely.

To Remove Worm Shaft End Play. Loosen the housing clamp bolt *C* one-half turn and loosen the adjusting nut clamp *I* sufficiently to allow the adjusting nut *D* to be turned. Next, screw the adjusting nut *D* down as far as it is possible without stiffening the action of the steering wheel while turning through its entire range. Use care when doing this to turn the adjusting nut *D* downward only, as it must be in positive contact with the bearing when the adjustment is completed. The clamp bolts *C* and *I* should then be tightened securely.

To Remove Backlash between Worm and Roller. Locate the wheels exactly in the straight-ahead position. This is very important. Now disconnect the drag link from the pitman arm and move the arm fore and aft to determine the amount of backlash. Next, loosen the five cover stud nuts *E* one-quarter turn only. Also the torque arm nut *J*. Now loosen nut *F* one-half turn only. With one wrench on the eccentric bolt *G* and one on the eccentric sleeve *H*, turn *G* in the clockwise direction and *H* in the opposite direction in gradual stages, noting the result by moving the pitman arm at each step and using care at the last stage to turn *G* and *H* just sufficiently to remove the backlash and no farther. If *G* and *H* are turned more than necessary, damage to the gear will be the result. In most cases one-eighth turn of the eccentrics *G* and *H* should be sufficient. Now tighten the nuts *E*, *F*, and *J* securely and connect the drag link. Check the backlash at the hand wheel. In straight-ahead position, the wheel should not be tight but should have no backlash. When properly adjusted, the gear will be without backlash in the **straight-ahead position only.**

NASH BALL-BEARING STEERING COLUMN

Fig. 66 illustrates the use of ball bearings in the steering column of the Nash 1935 automobile, in the left view. The right view shows the application of ball bearings in the roller which contacts the worm mounted on the steering-column shaft. It will also be noted that taper roller bearings are used in the worm mounting, taking the up and down thrust as road shocks are encountered and transmitted through the arm and through the ball-mounted roller gear.

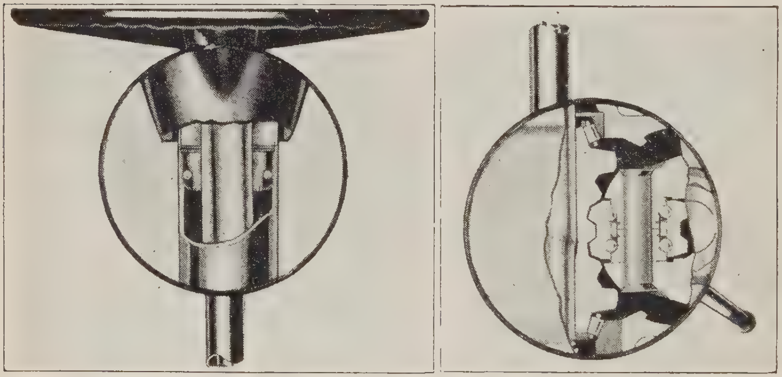


Fig. 66. Ball and Roller Bearings in 1935 Nash Steering Gear

PITMAN ARM STOP

Fig. 67 illustrates the pitman arm stop incorporated in the 1935 Chevrolet. This consists of a heavy steel stamping bolted onto the car frame by means of the mounting bolts for the steering gear. Bosses provided on the pitman arm are designed to contact the shoulder of the stamping, so that when a proper limit of travel has been given to the rotation of the front-wheel spindle bodies, the boss on the pitman arm contacts the shoulder on the stamping, thus preventing contacting of tires with the frame or other portions of the car chassis. This takes the place of "stops" on the front axle or knee action.

SHORTER PITMAN ARM

In order to facilitate steering, a number of the 1935 cars incorporated a shorter arm for the steering gear. Shortening these arms has served to limit the travel of the drag link within a fixed degree of rotation of the steering gear, while at the same time it has also permitted the use of shorter third arms and results in a general stiffening up of these parts. If the length of the third arm on the steering knuckle is not decreased, and the length of the pitman arm is decreased, there is naturally a greater leverage exerted for steering the car, without increasing the amount of energy required to move the steering wheel.

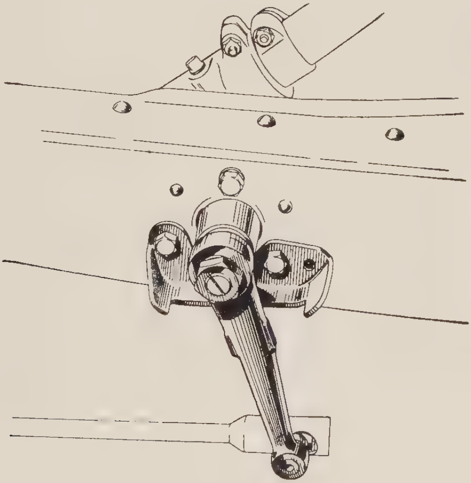


Fig. 67. Chevrolet (1935) Steering Gear

The Chevrolet steering gear illustrated in Fig. 67 has a 17½ to 1 ratio.

STEERING GEAR TROUBLES

Lost Motion and Backlash. Lost motion of the steering wheel does not always indicate that the steering gear is at fault, for wear in the steering-gear assembly usually takes place first in the clevis pins, yokes, and connections of the drag link. The spindles, spindle bolts, and wheel bearings are factors. Despite the fact that the front road wheels are deflected but a few degrees the spindles, bolts, or bushings may be worn, as these parts are subject to radial and thrust loads. The spindle bolt, which does not move, tends to wear oval; adding to this tendency the wear of the spindle bushings, one has considerable lost motion to contend with. Wear of the wheel bearings contributes to the apparent lost motion of the steering gear as do the connections of the drag link. Taking all of these factors into consideration, and allowing but a small fraction of an inch for play of each worn part, the sum total may result in considerable movement of the hand wheel before the road wheels are deflected.

Lost Motion in Wheel. While there should be a certain amount of movement to the hand wheel before it actuates the road wheels, the lost motion, as a rule, does not exceed ¼ or ⅜ inch when the gear is new. This amount is essential as without some free movement the steering of the vehicle would be tiresome. Wheels may be keyed or pinned to the column. When play exists as the result of a worn key, pin, or slots, the remedy is to re-cut the seats and make and fit a new key or pin. With some types of wheels the use of a wheel puller will be necessary to displace them. Another cause of lost motion, when the wheel is tight and linkage free from play, is a loose key retaining the worm or gears of the steering gear proper. A simple test of the hand wheel is to hold the tube, or post, securely and move the hand wheel. The amount of play in the drag link can be ascertained by grasping it about midway and trying to move it backward or forward or in the normal direction of travel. Hold the ball arm of the steering gear when making this test.

Lost motion in the drag link is caused by the ball and the blocks that rub against the ball becoming worn. In practically all drag links, there is an adjustment to take care of this and it is to be found at both ends of the drag link. In some drag links, the adjustment consists of a cap that screws over the end of the drag link tube, while in other types it is a slotted thread piece that screws into the tube. The spring tension is increased when the adjustment is tightened and holds the block in closer contact with the ball, thus removing the lost motion.

The amount of backlash present in the irreversible and semiirreversible types of steering gears may be determined by disconnecting the drag link, grasping the ball arm, and moving it up and down and back and forth. Worn bushings in the steering-gear case are frequently the cause of movement of the column as a whole. Another component that should not be overlooked in the search for the cause of lost motion is the ball arm. Movement of this member on its shaft can usually be eliminated by tightening the nut.

Wheel Wabble. This trouble may be caused by several things or a combination of things. Loose steering gear parts, such as steering knuckles and steering-knuckle pins, axle out-of-line, axle needs more caster, or too much backlash in the steering wheel. A careful inspection should be made for loose parts and if any parts show wear they should be renewed. Tighten all loose parts so that the steering gear is a little tighter than before. The axle should be lined up in regard to gather, camber, and caster, and the wheel bearings should be in good condition and correctly adjusted.

Cross-Rod Connections. Lost motion, noise, and rattle can often be traced to loose cross-rod connections. This part of the steering gear should be inspected occasionally because the clamp bolts, that hold the connection tight, are very apt to work loose. This not only causes the wheels to get out of alignment but it is also very dangerous as the thread on the cross-rod might strip and all steering control would be lost resulting in a serious accident. If the connections are allowed to remain loose, the rod and connecting clevis will become worn with the consequent need of renewal of all parts concerned.

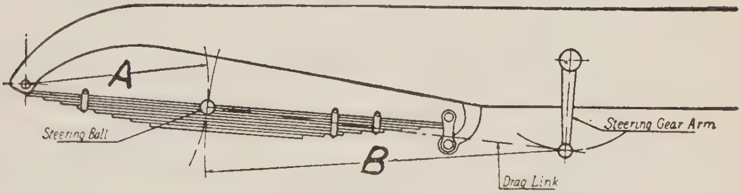
Tires Wearing Out Quickly or Unevenly. Although the tires are not actually a part of the steering gear, the condition of the steering gear has a great deal to do with the amount of service obtained from the tires on the front wheels. If the wheels are not correctly lined up, that is, have the correct amount of gather and camber, the front-wheel tires will wear out very quickly. Tires have been known to wear out within a few hundred miles from the above cause. When driving toward the curb, care should be taken not to strike the curb because this shock will often throw the wheels out-of-line and the driver will not notice it and the damage to the tires will occur before the condition is discovered. Worn steering-knuckle pins and bushings will alter the camber of a wheel and will cause tire wear. A rim that is not true on the wheel, as well as a loose rim, will cause excessive wear on the tires.

Lubrication of Steering-Gear Assembly. The proper lubrication of the steering-gear assembly adds to its life, but this work is not, as a rule, thorough. The steering gear proper should be packed with grease, the ball and socket joints of the drag link and steering-arm lever with a light grease; the clevis pins also should be lubricated. The steering-knuckle pins are provided with either grease or oil cups.

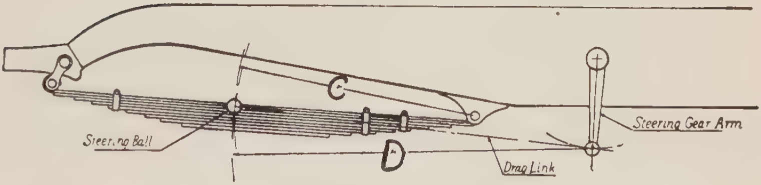
A point generally overlooked in the lubrication of the steering gear is the steering-post spark shaft and throttle-sector anchor tube, shown in the illustration at Fig. 41, which is of interest in that it illustrates the assembly of the Packard car. The post carries the control-box unit. The spark shaft and throttle tube frequently lack lubricant and should be cleaned and coated with a graphite grease before replacing when the gear is being reassembled. The lower extremity of the spark and throttle members carry levers or small bevel sectors which operate the linkage of the ignition apparatus and carburetor. Clamping screws are often used to secure these parts.

Tire Inflation. The cord tires, which were standard equipment on passenger cars for many years, employ pressure as high as 70 to 80 pounds per inch. Balloon tires, when first adopted by car manufacturers, carried pressures as low as 20 pounds per square inch. In order to have the balloon tire carry as great a load as the cord tire, the size of the tire and the amount of air used were increased in a direct ratio to the decrease in air pressure. This resulted in balloon tires which were very large, and which set up so many problems that it was deemed best to decrease the size of the tire somewhat and increase the pressure slightly. Best practice indicates the use of a middle size balloon tire, considering the weight being carried. The air pressure is somewhat higher than that formerly used in balloon tires.

Increasing the air pressure in the front tires has done considerable to eliminate some of the evils encountered with the first application of these tires. Perhaps the greatest evil encountered was that of the front wheel wabble or shimmy. This is a condition which exists when the front wheels tend to shake from side to side. Another evil encountered with the very soft balloon tires was what is known in some quarters as front-wheel tramp. This is somewhat different from the front-wheel wabble and is sometimes spoken of as "high-speed shimmy." It seems that this tramp is set up when one front wheel is going down on to the soft tire while at the same instant the other front wheel is coming up from the roadway, so that a sort of teeter-totter effect is secured. A great many items of design outside the tires enter into both shimmy and tramp. Balancing the weight of the rotating units helps to eliminate the tendency of a shimmy or tramp. Most balloon tires are marked at a point which indicates either the light or heavy point of the casing. When mounting a tire so marked, the tube stem is placed at the light position so that its weight tends to offset the unbalanced weight of the casing and thus balance the entire unit.



Shackle at Rear End



Shackle at Front End

Fig. 68. Shackling a Front Spring at the Front End to Eliminate Front-Wheel Wabble

Spring Shackling and King Pins. The type of king-pin or pivot-pin bearing or bushing has an influence on the performance of the front axle. The hook-up of the steering gear and front axle linkage must be so designed that the spring action does not overly influence the motion of the front wheels. It is quite possible for a front end to be so hooked up that the spring action, when traveling over a rough road, will cause a shimmy to be set up in the front wheels. In order to avoid this, car manufacturers make use of the form of spring mounting which is illustrated in Fig. 68 in the lower view. In this figure it will be noted that the two conventional forms of spring mounting are illustrated. The view at the top shows the spring shackled at the rear, and the one at the bottom shows the spring attached to the car frame at the rear and shackled at the front. The purpose served by this is illustrated by the radii A and B in the top figure and by C and D in the lower figure.

It will be noted that the spring action, in the case of the upper figure, on striking a rough spot causes the steering ball mounted on the front axle spindle body to travel according to the radius A, and the drag link which connects the steering ball and the steering gear arm will travel on the radius B. It will be seen that the two radii oppose each other and, owing to this other fact, there is a tendency to set up front-wheel wabble.

This is overcome in the case of the lower figure, which shows the spring shackled at the forward end. Since the steering ball will follow the curve of the radius C, which is approximately that of the radius D, which is that of the drag link, the front axle and steering gear parts are held in approximately the same alignment, irrespective of spring action.

Ease of Steering. The amount of surface in contact with the street in the case of balloon tires is considerable, and the effort required to steer a car is in direct ratio to the amount of surface thus in contact. Ease of steering seldom entered into the consideration of the car builder when cord tires were used, since almost any steering gear ratio gave ample steering power.

Both the front-wheel brakes and balloon tires affected ease of steering and resulted in the development of entirely new types of steering gears. In the first attempt to perfect steering gears when the change-over was necessary, the worm and sector, worm and gear, screw and nut, and other of the older types of gears were adapted to the new duties by increasing the ratio between the hand wheel and the pitman arm. This resulted in such slow steering in some instances that it was found difficult to bring a car around the curve at anything like the speed the car would ordinarily have safely made on a curve. Gear ratios as high as 15 and 20 to 1 are used. This is practically double the ratio used for the older designs.

SPRINGS AND SHOCK ABSORBERS

SPRINGS

Automobile springing or suspension has passed through a long series of developments. Early automobiles made use of types of springing similar to those formerly used for horse-drawn vehicles. This led to the early adoption of the full-elliptic springs, the three quarter-elliptic and the semi-elliptic springs, common forms of which are shown in Fig. 1. Some of the very early models made use of a semi-elliptic mounted after the fashion of the old side bar buggy springs. Later, the use of the platform type spring *C*, Fig. 1, which is formed from two semi-elliptics over the axle and a third semi-elliptic transversely mounted at their rear. Contemporary with this was the use of the full-cantilever spring *D*, Fig. 1, for rear axle suspension and the semi-cantilever or quarter-elliptic *F*, Fig. 1, for front spring suspension. All of these springs are known as the plate or leaf type of construction. Of the entire group, the semi-elliptic only has survived to find a field of service in modern automobiles.

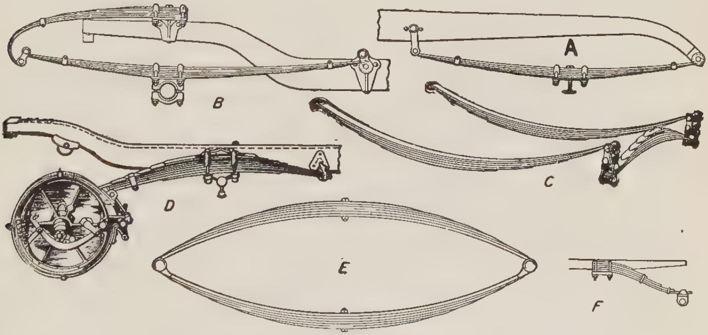


Fig. 1. Leaf Spring Types, *A*—Semi-Elliptic; *B*—Three-Quarter Elliptic; *C*—Platform; *D*—Full Cantilever; *E*—Full Elliptic; *F*—Cantilever or Quarter Elliptic

Practically all automobile manufacturers make use of the long semi-elliptic spring for mounting the rear axle. Experiments under

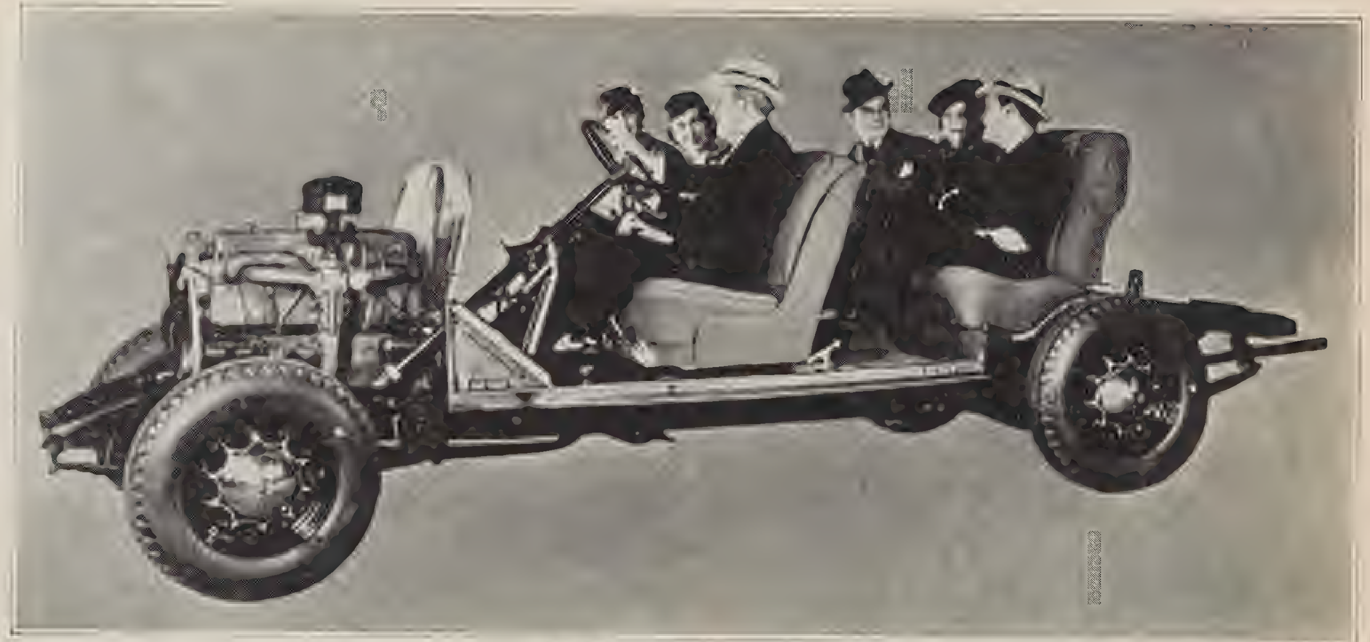


Fig. 2. Nash Balanced Ride

way may see a change here similar to that which has appeared with reference to the suspension for the front axle. Both coil springs and leaf springs are utilized for front suspension, as will be explained in the following paragraphs. The principles underlying the springing and suspension of the automobile have undergone certain changes, as the engineers have studied the problem throughout the years. For instance, the general practice for many years was that of carrying more weight on the rear axle than was carried on the front axle. The idea formerly held that since the front axle was designed for steering the car, it should not carry weight in amounts equal to that imposed on the rear axle. Then, too, the use of two-wheel brakes for many years had its influence. Gradually, however, the practice of applying equal braking effort to the front wheels as compared to that on the rear wheels led to the conclusion that the front axle might carry weights equal to the rear axle. The general plan of modern design is to have approximately equal weights and equal braking effort distributed tc front and rear axles and wheels.

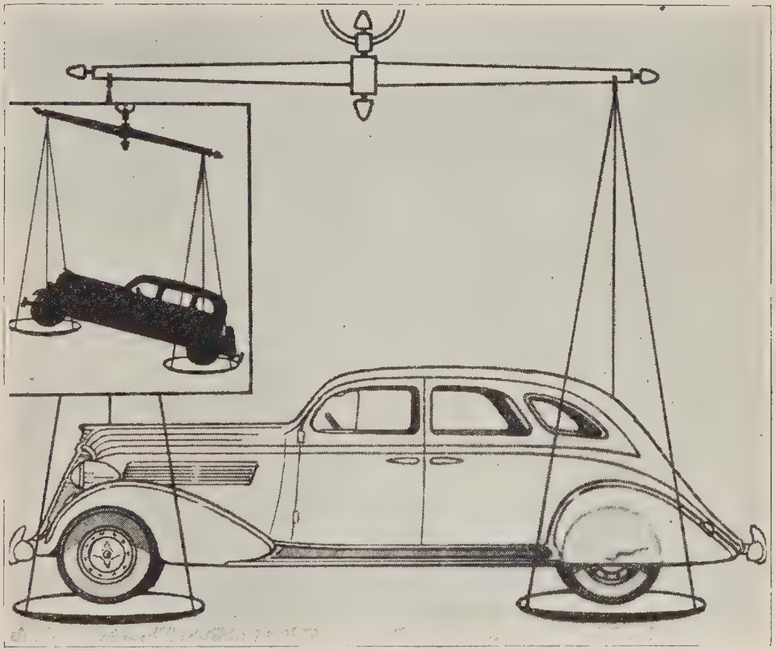


Fig. 3. Balanced Ride Car Compared to Rear Heavy Car

Nash Balanced Ride. For almost two score years automobiles had more weight at the rear than they had on the front axle. This was long considered good practice inasmuch as it resulted in better traction in bad going. Improved road conditions led to higher car speeds and, eventually, the demand on the part of the public for cars which offered a better ride. In order to secure a better ride, consideration was given to the spring rate. This was an attempt to have the front springs made approximately as soft as those at the rear. In the old cars the inequality in rate between front and rear springs (meaning by this, the number of pounds needed to deflect the spring one inch) caused the front springs to bounce in a short jerky motion, while the more flexible rear springs bounced more slowly. This uneven movement between the front and rear springs, resulted in back seat pitching and neck snapping.

In addition to making the springs more nearly of equal length, the Nash balanced ride, as illustrated in Fig. 2, shows the engine moved forward quite a distance, until the front end is over the front axle, and both front and rear seats moved forward until all passengers are riding between the axles, rather than those in the rear seat riding over the axles.

This distribution of weight is illustrated in Fig. 3 where the insert of the car on the balances shows the rear of the car very much heavier than the front. In the case of the balanced ride, illustrated in the larger view, the car is shown with exactly the same weight on the front wheels as on the rear wheels.

Semi-Elliptic Springs. The conventional semi-elliptic spring front axle suspension is illustrated in Figs. 4 and 5. The construction of these springs is typical of good design. The plates are held together by means of clips which are used at points designed to tie them together, which is necessary to prevent spring breakage under rebound conditions as well as conditions set up with the application of the brakes which induce a direct reaction in the springs, tending to mal-form them. The spring shown in Fig. 1 has the forward end bolted to the car frame by means of a bracket. The rear end of this spring is shackled to the car frame. This is the older design. Another design of long standing is the spring mounting shown in Fig. 2 where the rear end of the spring is bolted to a bracket which in turn is rigidly attached to the car frame, while the forward end of the spring is shackled to the frame horn. The feature of design entering into the shackling at the forward end of the spring rather than the rear is the one explained in the section covering steering gears in connection with Fig. 68.

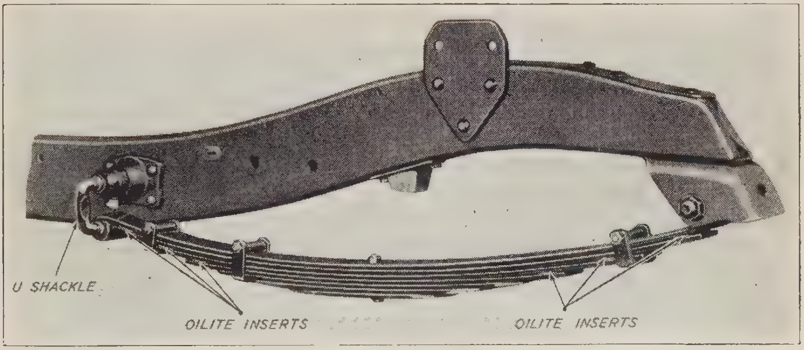


Fig. 4. Dodge Front Semi-Elliptic Spring Fitted with Oilite Inserts
Courtesy of Dodge Brothers Motor Car Company

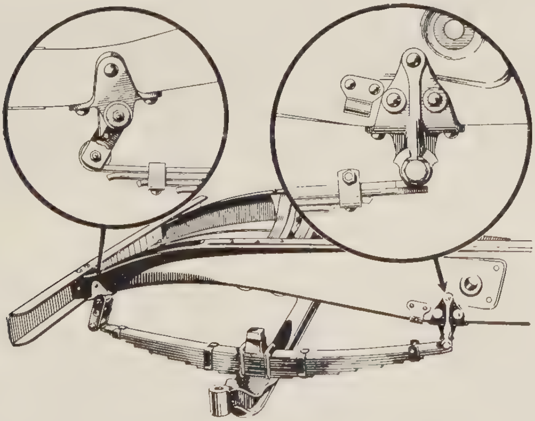


Fig. 5. Chevrolet One-and-One-Half Ton Truck Spring

Leaf or plate springs may be designed to carry any load desired. If they are too heavy for the load, the car will ride hard. Road shocks will come through to the passengers very sharply and make for uncomfortable riding. If the spring is too long and soft, there will be too much swinging to the car and the spring may bottom under heavy shock. These characteristics are so well understood that car manufacturers generally provide different weights of springs for different models, varying the weight of the spring but increasing or decreasing the number of leaves or plates as the difference is marked or by varying the thickness of the plates if the difference of load is less marked. The tendency in leaf spring design has been to increase the length of the front springs when leaf springs are used and to decrease the thickness of the plates so as to make for softer spring action. The quality of the ride of the automobile is often determined by the length of the spring and the thickness of the plates. Another feature which enters in here is the relation in length as between the forward and rear springs of the automobile. It is for this reason that front springs when of the semi-elliptic type have been increased in length so as to more nearly approximate the action of the rear springs. Also, this reason accounts for the introduction of independent wheel suspension. By using the coil spring, it is claimed to be possible to have front springs just as flexible as rear springs and at the same time afford spring action timed to act in unison with the vibrations of the rear spring so as to prevent the uncomfortable and undesirable car action which tends to pitch passengers from the seat of the car.

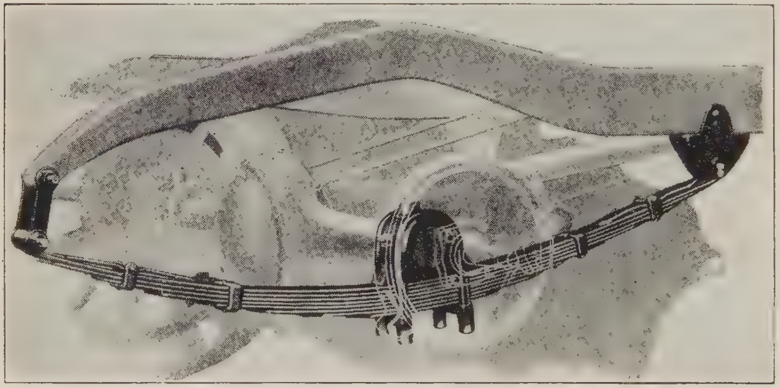


Fig. 5A. Chevrolet Semi-Elliptical Application
Note the rebound check leaves.

Hotchkiss Drive. The adoption of the Hotchkiss drive, Fig. 5A, in which the rear axle is connected with the frame through the chassis springs only, making the springs perform the functions of torque and thrust, is a radical departure from previous forms. The objection that it subjected the springs to unnecessary strains has not been sustained in practice, which has shown that a slight yielding of the rear axle when starting and braking, by a certain flexure in the springs, has reduced the stresses upon the transmission members.

In the Hotchkiss drive, the springs are rigidly attached to the rear axle, while the front end of the spring is secured to the frame with a proportionately large bolt through which the drive is transmitted. Users of the drive claim that it is quieter, that the car holds the road better, that it is more flexible, and that it avoids the road shocks which are transmitted through stiff torque members from the axle to the frame. Makers who drive through the springs and employ other torque members claim that they are not sacrificing flexibility in driving while eliminating a certain sidesway and other strain prevalent when the springs perform the functions of the torque. In the Hotchkiss drive, two universal joints in the drive shaft are used.

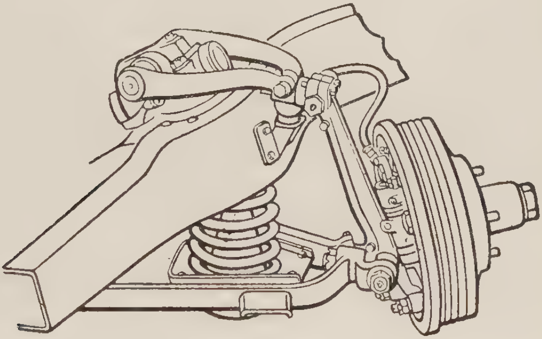


Fig. 6. Coil Spring Used in Front Suspension

Coil Springs. The adoption of coil springs for front wheel suspension, Fig. 6, in what is commonly termed knee-action cars has served to set up entirely new problems with reference to spring suspension and service. This is covered in the first sections of this volume. The prime purpose of introducing the coil spring is to give a softer ride and at the same time to give a spring action which is in time with the spring time of the rear springs. The rear springs are longer than the semi-elliptic ones formerly used on this type of automobile. This is spoken of as spring rate and reference is had to the relative rate of deflection of the spring after striking an obstruction in the road. By introducing coil springs, the rate of spring is controlled much more readily.

Independent Front Wheel Suspension. The widespread adoption of coil springs for front wheel suspension, as pictured in Fig. 7, is a definite attempt to secure freedom from pitching and tossing of the car body. Uniform distribution of weight in combination with knee-action wheels tends to promote the safety and roadability of the cars, since pitching and tossing always tend to take the car out of steering control. The Oldsmobile system of independent springing, shown in Fig. 7, utilizes two V-shaped control arms. The upper arms are an integral part of the shock absorbers, while the lower arms, which are of I-beam construction, are fastened to the frame by means of threaded bearings. Both the lower and upper arms are connected to the steering knuckle as shown. The points at which they are connected are subject to adjustment for maintenance of the castering effect. The coil springs are made from silicon manganese steel. These springs are ground and polished before they are formed. This is necessary to prevent any slight imperfections in the spring steel, tending to develop fracture at a later time. When formed and properly mounted in position, the action of the spring is what is termed soft. The spring wire for each spring is 90 inches long before it is coiled. The springs rest on pads between the lower control arms and

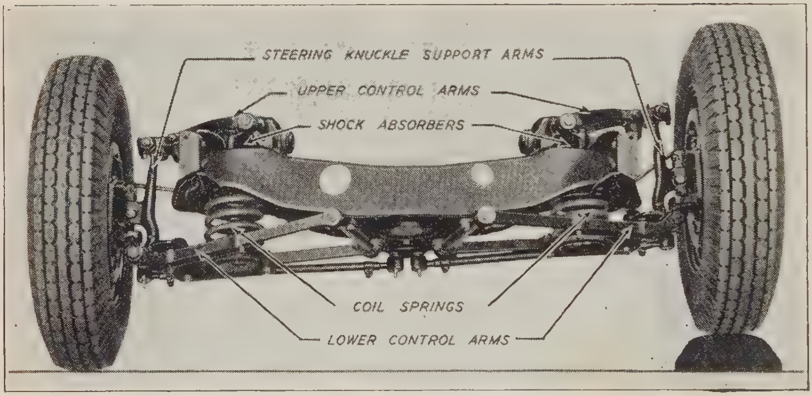


Fig. 7. Coil Springs Used for Oldsmobile Knee-Action Front Suspension
Courtesy of Olds Motor Works

the frame side rails. Distance between the supporting points of the control arms make for a very rigid support so that the propulsion of the wheel is definitely controlled. Under conditions of road shock one wheel may move in a vertical direction without affecting the opposite wheel. When brakes are applied, the torque developed is absorbed by these control arms, the wide ends of the control arms with their points of mounting having a definite advantage here. These soft coil springs are definitely controlled by the shock absorbers.

Chevrolet Front Wheel Suspension Unit. The Chevrolet knee-action is manufactured under the Du-Bonnette patent. As shown in Fig. 8, the wheel hub and drum is supported on the spindle which is rigidly attached to the rear end of the swinging arm. This arm is attached to a cross shaft through the housing. A cam on this cross shaft serves to actuate the heavy coil springs enclosed in the housing and thus carry the load of car and passengers. This entire unit is mounted on a king pin and swivels or turns with the wheel as the wheel is turned.

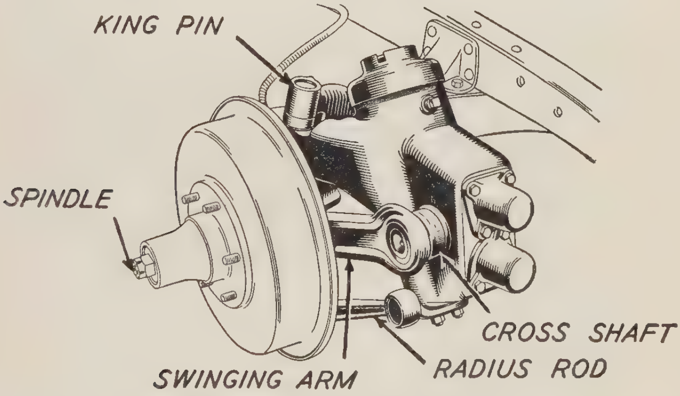


Fig. 8. Chevrolet Knee-Action Suspension
Courtesy of Chevrolet Motor Company

The coil springs in the knee-action units are made of high carbon steel, ground and polished to a mirror-like finish before forming. The wheel support, or swinging arm and the radius rod are made from special analysis steel with a tensile strength of over 130,000 pounds per square inch. In case of a severe side shock, as when striking the curb, the wheel support arm can move inward approximately $\frac{5}{16}$ inch, at which time it will contact the king pin support. This support is one of the most rugged units of the entire frame, in fact, it is bolted to the car frame in a manner designed to absorb all heavy shocks. When the force of the shock is relieved, the wheel support arm swings back to its normal position. Since the elastic limit of the arm is well over 1 inch, this minor movement is of no consequence.

Ford Center-Poise Springing. The Ford transverse method of spring mounting on the 1935 cars includes new front and rear spring designs, a new frame, radius rods and other allied parts. The front spring is $7\frac{5}{8}$ inches greater in length and $\frac{1}{4}$ inch wider. The bow in the rear spring has been eliminated. It is also $\frac{1}{2}$ inch longer. The deflection rates of both front and rear springs are materially lower. That of the front is approximately 290 pounds per inch and that of the rear, 190 pounds per inch, thus both springs have approximately equal flexibility. The longer front spring contributes to car stability when making turns.

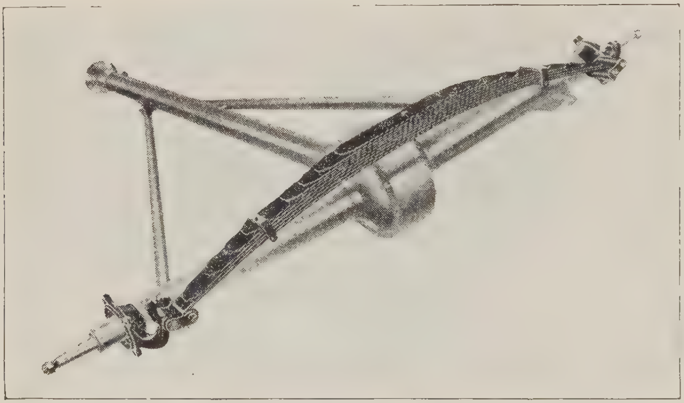


Fig. 9. Ford "V-8" Rear Axle with Spring Suspension to Rear of Axle Housing

The front spring is placed about 4 inches ahead of the axle, corresponding to the placement of the rear spring, about 7 inches behind the axle. The spring base, or distance between the points of attachment of the front and rear springs to the frame, has been increased from 117 to $123\frac{1}{8}$ inches, a gain of $6\frac{1}{2}$ inches without altering the 112-inch wheel-base.

The spring shackles are attached to forged perches welded into the ends of the radius rods, both front and rear, to which the axles are also attached. The radius rods are of larger rectangular section, tapering toward the center mountings on the X-member and torque tube. Axles may be removed without disturbing the spring mountings.

Since the compactness of the "V-8" engine provides good space for passengers, advantage was taken of the more forward position of the engine, to move the front and rear seats forward a corresponding amount. Both front and rear-seat passengers are thus placed closer to the center of the chassis, hence have less vertical motion relative to the ends of the chassis, the rear-seat passenger weight resting 8½ inches forward of the former position. No matter how many passengers are in the car, or where they are placed, the weight on the front wheels will never be appreciably greater than on the rear, so that in no case can front end heaviness affect control of the car on slippery road surfaces.

Ford "V-8" Springs. The spring suspension of the Ford "V-8" is illustrated in connection with the rear axle in Fig. 9, where it will be noted that the rear spring is hung on outriggers which are part of the brake backing plate mounting. The later type springs are made with thinner ends and the leaves of the spring are more numerous as well as thinner. This serves to give a more flexible spring action and promotes ease of driving. By mounting the spring to the rear of the rear axle, it is possible to have the center of gravity of the car lowered to a marked degree. The Ford automobile has for a score or more of years made use of the transverse spring mounting. This is described more fully in subsequent paragraphs which deal with the Model "A" springing, which is quite similar to that used on the "V-8."

Ford. The form of the Ford spring has always been distinctly different. Fig. 10 shows the front and Fig. 10A the rear spring used on Ford cars, the distinction in the front spring being principally in the use of a single ordinary inverted front spring set across the frame on top of the axle, where most makers use a pair of side springs. The spring is an inversion of the usual semi-elliptic type, the set being downward instead of upward. A third claim to distinction is in the use of vanadium steel, which, it is claimed, has a higher tensile and compressive strength than any other steel, and it is practically unbreakable in torsion.

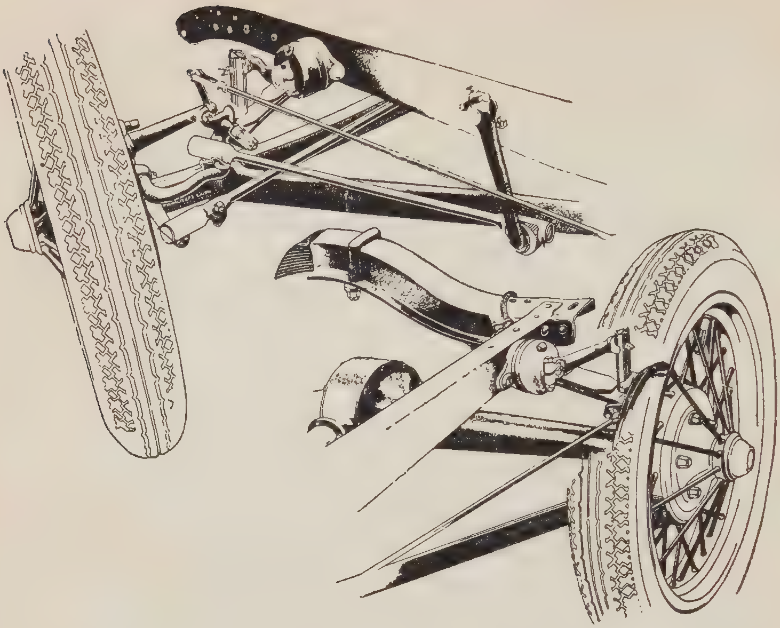


Fig. 10. Ford Model "A" Front Spring, Front Axle, and Shock Absorber Assembly

Fig. 10A. Ford Model "A" Rear Spring, Shock Absorber, and Rear Axle Assembly

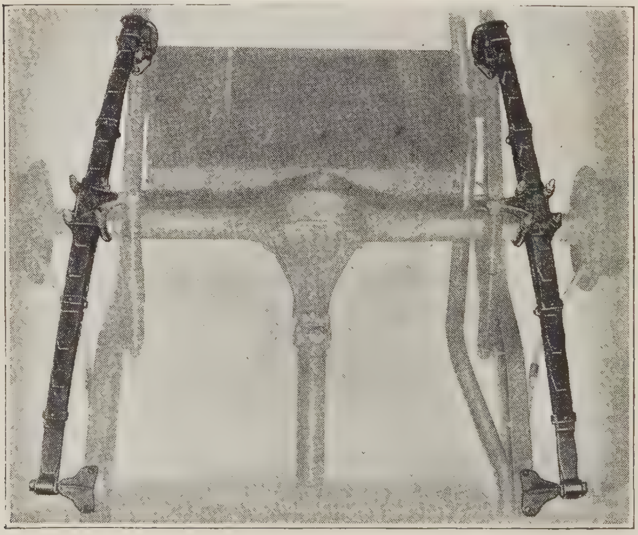


Fig. 11. Hudson-Terraplane Splayed Spring Mounting

Hudson=Terraplane 1935 Ride Control. Fig. 11 illustrates a worm's-eye view of the splayed rear spring construction which provides for a very wide support of the car and assures greatly increased road stability, owing to the fact that when springs are set on in this order, there is a marked tendency to resist sidesway. The rear springs have been made more nearly straight, or flatter than formerly.

Direct-acting shock absorbers illustrated in Fig. 12 are incorporated in the design. These shock absorbers have replaceable valves which make it possible to secure any individual type of ride desired, under any set of given conditions. This is of value when a car is being used in territory where road conditions are different from those usually encountered. When the new valves have been installed, it is not possible to change the ride without again making a valve change. No adjustment is provided on the shock absorbers other than the valve change mentioned.

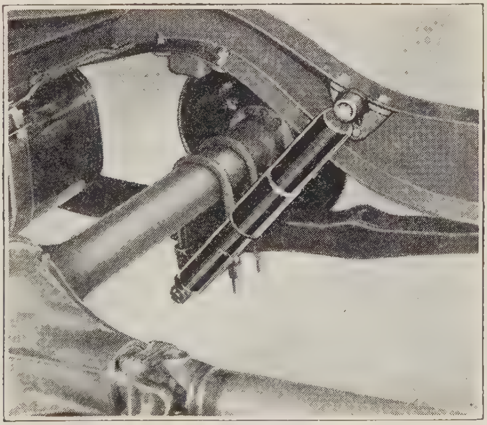


Fig. 12. Hudson-Terraplane Shock Absorber

Oilite Spring Inserts and Bushings. Chrysler engineers have developed and patented a product known as "oilite." This is of considerable interest to the student inasmuch as it is incorporated with Chrysler Motor products, especially with reference to their spring lubrication.

The type of spring inserts and bushings which may be made from this special product is shown in Fig. 13. Bushings may be used

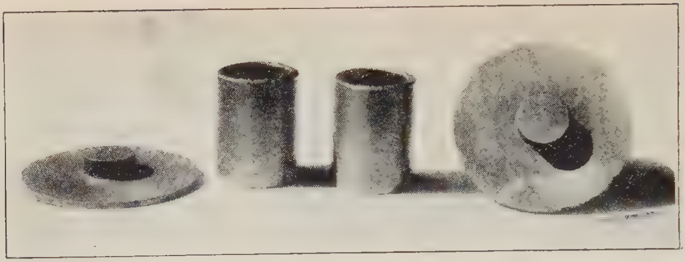


Fig. 13. Oilite Spring Inserts and Bushings

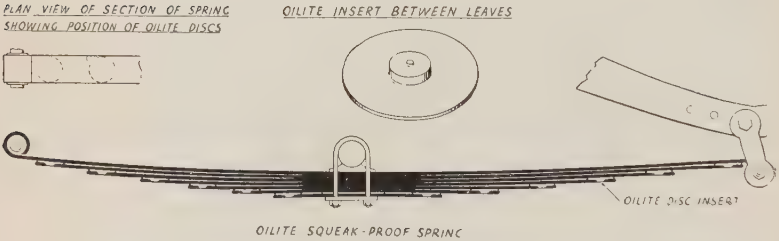

PLAN VIEW OF SECTION OF SPRING
SHOWING POSITION OF OILITE DISCS
OILITE INSERT BETWEEN LEAVES
OILITE DISC INSERT
OILITE SQUEAK-PROOF SPRING

Fig. 14. Oilite Inserts in Chrysler Springs

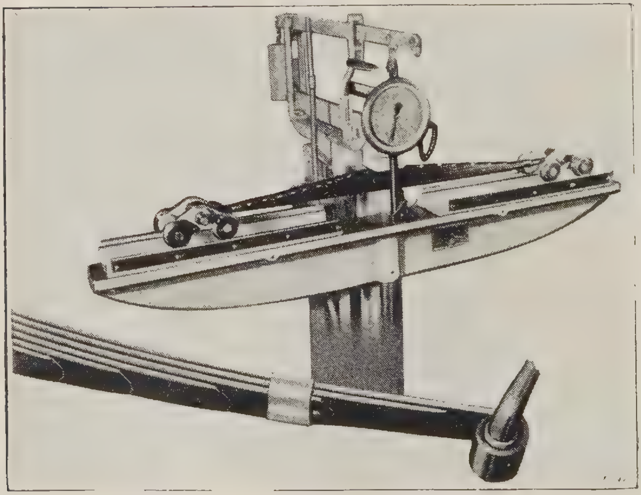


Fig. 15. Chrysler Tapered Leaf Spring Under Test

for water pumps, spring shackles, steering gears, propeller shafts, and similar points of service. These appear in the center of Fig. 13, and the spring inserts appearing on the ends in this figure are shown in diagrammatic form as they are inserted in the springs illustrated in Fig. 14.

Uniform flexing and oscillation of the new spring are accomplished by keeping the spring leaves separated by placing oilite buttons or discs between them at both ends. The spring leaves do not touch each other from their ends where the oilite discs are located to the center where the spring assembly is held together by the spring bolt.

Oilite metal is forty per cent oil by volume. It is made from powdered virgin copper, tin, and graphite. These powders are very fine, so much so that the majority of this material will pass through a 300-mesh screen. These metals, in a definite proportion, are carefully weighed, thoroughly mixed, and fed into an automatic briquetting machine. Here the metal is formed under very high unit pressures to the final form desired. Subsequent operations are heat treating, impregnating with oil, and final sizing for correct dimensions.

The oilite buttons or discs between the ends of the spring leaves provide an oily film which provides constant lubrication and keeps the leaves from "freezing" together. It is this "freezing" of dry leaves that makes springs ride hard. The uniformity of the riding quality of the spring is constant at all times under all conditions.

Fig. 15 illustrates a method of testing spring action and proving length of spring life by simulating on the test machine action, such as the spring would give on the car when it was driven over the highway.

Silent U-Shackle. The silent U-shackle, such as is illustrated in Fig. 16, is used in spring mountings on a large number of passenger cars. The device in itself is novel. The advantage claimed for it is greater life, owing to the fact that the bearing is actually on threaded surfaces. Approximately five times as much bearing surface is available on these threaded U-bolt ends as would be available on similar plain surfaces.

There are three parts to each of these U-shackles. Two of the parts are the upper and lower threaded bushing, the other part being the U-bolt. The steel bushings are threaded into the frame and into the spring eye, while the U-bolt is threaded freely into the steel sleeve or threaded bushing. It will be seen that a free movement between the steel bushings and the U-bolt sides or ends is thus guaranteed. The threads are a free running fit, being .010 inch to .020 inch loose.

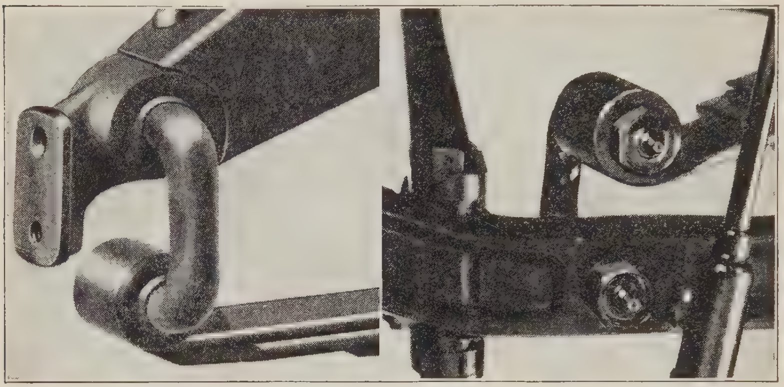


Fig. 16. Left—Closed End of Silent U-Shackle; Right—Opened End of Silent U-Shackle

These U-bolts may be installed with either the open or the closed ends out. Where the closed ends are out, lubrication of course is easily accomplished since the open ends carry the alemite or zerk fittings. The lubricant is introduced into the steel bushings through these greased fittings from the open ends and the only way for it to find its way out is along and around the threads to the rear or the end opposite the fitting. It will be seen, of course, that

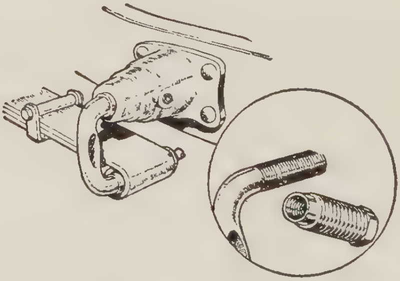


Fig. 17. Details of Construction of the U-Shackle

this leaves very little room for any dirt or water to work in. The amount of lubricant contained is very much greater. The details of construction of the threaded end of the U and the bushing are shown in Fig. 17. Note that the threads on the bushing outside are coarse, while those on the bolt which take those inside the bushing are finer pitch.

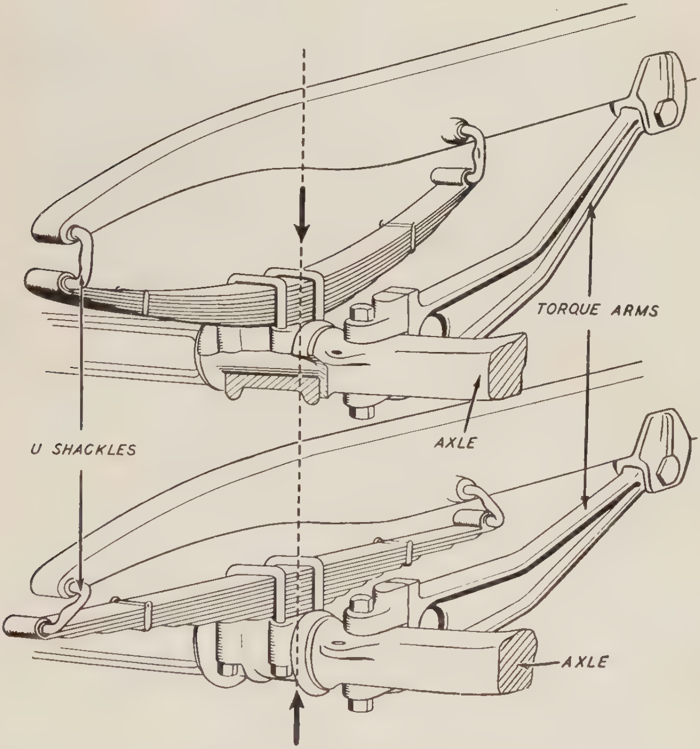


Fig. 18. Action of the U-Shackles on the Terraplane
Courtesy of Hudson Motor Car Company

Hudson-Terraplane Front Spring Shackle. The action of the U-shackles on the front of the Hudson and Terraplane cars is illustrated in Fig. 18 which shows in the upper view the relative position of the front spring, the radius arm control, the front axle beam, the car frame, and the opened end U-shackles, one of which is on either end of the front spring, when all of these parts are in the rebound position. The lower view shows what happens with reference to the action of these U-shackles when the spring is straightened and moved upward under heavy loads. Owing to the long sweeping radius of the radius arm, as compared with the shorter radius of the spring when one end of it is bolted to the car frame, it is found that the relative position of the front axle with reference to the car frame remains unchanged under a severe road shock which tends to straighten the spring, as shown in the lower view. In other words, instead of the front axle moving its position to accommodate itself to the action of the spring, the contrary is true and each end of the front spring is free to move outward so as to accommodate the length of the spring to the straightening and curving under rebound without changing the relative position of the front axle with reference to the car frame. The arrows and dotted line in Fig. 18 illustrate the action.

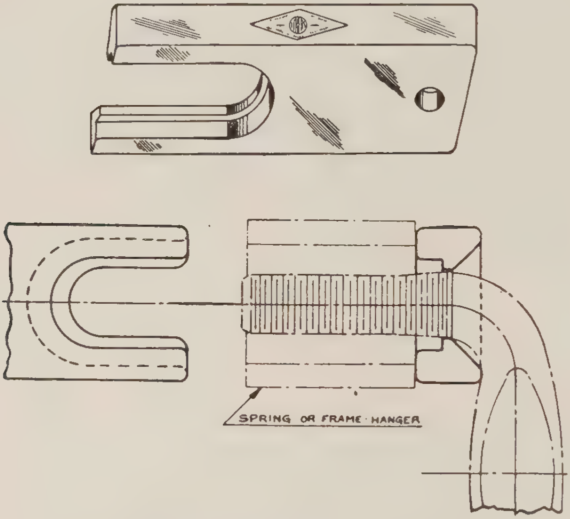


Fig. 19. Dodge Spring Shackle Gauge
Courtesy of Miller Tool Manufacturing Company, Detroit, Michigan

Dodge Spring Shackle Adjustment. Where the semi-elliptic springs are installed on the Dodge cars, the U-shaped threaded type of spring shackle and bushing is used. To correctly align the semi-elliptic spring, the threaded bushings on both projections of the spring shackle must be adjusted.

The bushings should be threaded onto the shackle so that a specified distance between the bushing and the side of the spring shackle is obtained. A gauge, shown in Fig. 19, should be used for accurately checking this distance. A considerable force is required to thread on a new bushing into a spring eye, as the bushing must cut its own thread.

Threaded bushings must be tightened securely in the spring eye and spring hanger, but must not be so tight as to prevent the free movement of the shackle.

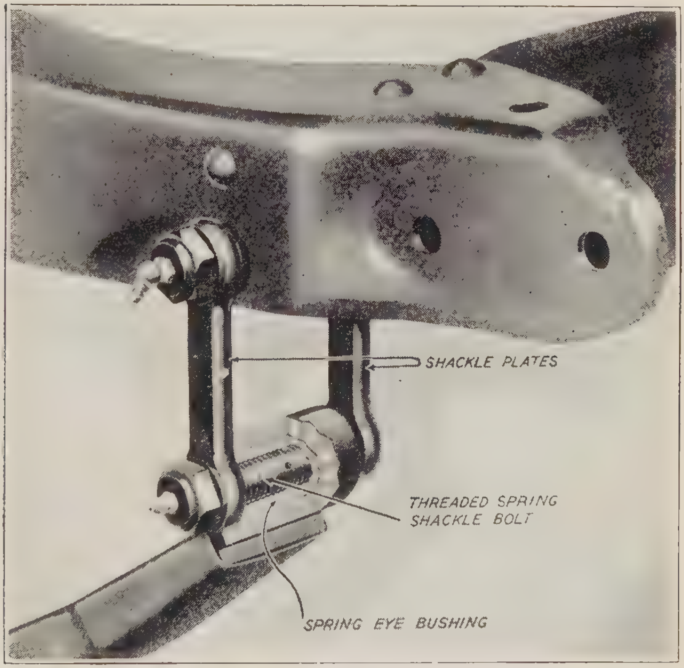


Fig. 20. Buick Threaded Spring Shackle
Courtesy of Buick Motor Company

Threaded Type Spring Shackle. The threaded or screw type shackle as used on the Buick is illustrated in Fig. 20. This particular type of shackle is used on a number of automobiles. The bushings and pins are hardened and machined to a nominal clearance of .008 inch. This permits room for the lubricant to be forced through and distributed over the entire bearing surface.

When assembling the shackle, the large shake-proof lock washer should be placed under the head of the bolt and the ball first secured under the shackle with the notches on its side. The bolt is then screwed between the bushing so that the operation between the bushing and shackle is ⅛ inch plus or minus $\frac{1}{32}$ inch. Continue screwing the bolt through the bushing and assemble the plain shackle so that it is also spaced to the above dimensions. This shackle is manufactured so that the threads on the bolt and in the shackles are such that they are a press fit in each other. It is extremely important that the bolt be securely tightened so that the shake-proof lock washer is entirely compressed.

Ford Spring Shackles. The spring hanger or shackle illustrated at *F* in Fig. 21 is typical of the style of hanger used on some millions of Ford cars. This U-bolt is forged in one piece and is provided with shoulders against which the bar *D* is placed after the bolt has been assembled in the perch and spring eye. The bushing shown above the bar *D* is pressed into the spring eye and receives one of the spring hanger bolts through it. Adjustment of these hangers is by means of the castel nut shown lying below the bar *D*. After adjustment has been made by pulling the nut tight, it is then loosened one castellation and the cotter key inserted to lock it. Lubrication is from the opposite side of the hanger through zerk fitting pressed into position.

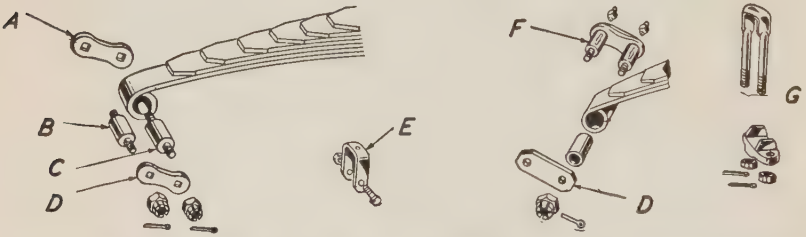


Fig. 21. Ford Spring Shackles, Clip, and Clamp, *A*—Bar; *B*—Upper and *C*—Lower Spring Shackle Stud Assemblies; *D*—Bar; *E*—Spring Clamp; *F*—Spring Hanger; *G*—Spring Clip and Clip Bar

Another style of hanger utilized in the Ford construction is that illustrated in the views *A*, *B*, *C*, and *D*. In this case the upper and lower stud assembly shown at *B* and *C* are assembled in the eye of the spring and the spring perch and then the bars *A* and *D* are assembled over the ends of the studs and locked and held in position by means of castel nut and cotter keys.

The device shown at *E* in Fig. 21 is a spring clamp. Spring clamps are made in a variety of forms and are used to clamp the leaves or the plates of the springs together, so as to prevent their opening up on rebounds. This particular clamp is riveted to the end of one plate and assembled to the spring by means of the bolt and nut which are shown. In many instances clamps are riveted to the spring plates by means of soft iron rivets and then instead of bolting them at their open ends, these ends are simply formed around the spring plates, being bent over to form a clamp.

The U-bolts which are used for assembling the springs to the spring bed on the axle, or to the car frame as the case may be, are usually termed spring clips and the bar which goes across the spring is termed the clip bar. The Ford spring clip illustrated at *G* is one used in connection with a certain model of the Ford trucks. This particular design makes use of castel nuts and cotter keys to secure the job. In many instances lock nuts are used on spring clips to prevent their working loose.

Metal Spring Covers. Many automobiles make use of the metal spring cover. The purpose of these covers is to retain the lubricant within the cover and assure a noise proof, comfortable spring action. In case of broken plates or spring rebuild, it is necessary to remove these covers. If extreme care is used in removing the old cover, it will be possible to re-use it. A locking seam is provided for holding them in position. If this seam is damaged when removing the cover, it will need to be discarded. The usual means of removing these covers is to place the spring in a spring loading machine shown in Fig. 22. The design shown is arranged to accommodate springs of varying length. After the spring is in position in the machine, which can easily be made in the shop, the jack is set on the movable pad and the spring is straightened by loading with the jack, which may be any car jack. A special 1-inch cape chisel, shown in Fig. 22, is used to drive under the closing strip from the side, along the entire seam, opening both sides. Next, use the screwdriver to pry the closing strip away from the cover. Before reinstalling the cover, first coat the spring well with a 50 per cent graphite lubricant. Next, install all canvas liners in position, leaving the canvas lap on the main plate of the spring. Next, place the cover assembly in position over the canvas liner. Use a C-clamp to hold the cover body light against the sides of the spring and apply the closing strip at one end. Move the clamp along, forcing the closing strip in position. Finally, when closing strip is in position, the seams should be hammered down at each end and then flatten the closing strip all along, working from the center bolt out. To insure a tight lock and smooth finish, use a short length of spring leaf with the curved surface down and then hammer over this to secure a neat, smooth finish. After the work has been completed, the jack can be removed and the spring removed from the loading jack.

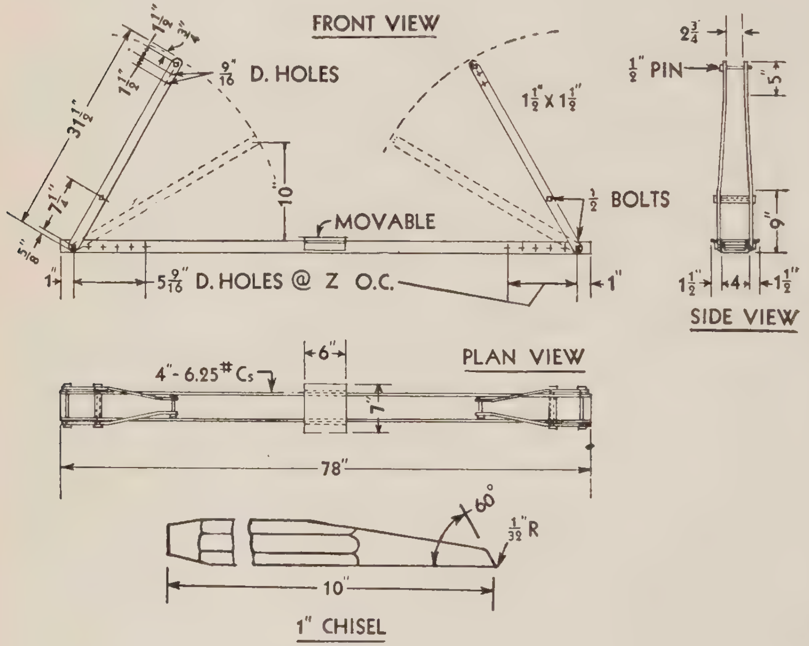


Fig. 22. Spring Loading Machine
Courtesy of Buick Motor Company

Lubricating Springs Which Are Provided with Spring Covers. As mentioned in the previous paragraph, springs are lubricated when they are assembled at the factory or when they are rebuilt. Experience shows that springs properly lubricated when assembled will operate for approximately 5,000 miles without any tendency to set up squeaks. After that period, to prevent squeaks and to maintain the proper riding qualities, springs which are provided with the metal covers should be lubricated. The covers are built with a special 3/16-inch hole on the under side approximately 6 inches from the spring eyes through which lubricant can be forced without removing the springs from the car, provided that the proper spring lubricating tools are used for this purpose. Fig. 23 illustrates the spring lubricating tool and the spring shown in part sectional view. It will be noted that the lubricating tool has the appearance of the ordinary C-clamp. The outer end of it is provided with an adjusting nut and screw. The inner end is provided with a sleeve much after the fashion of the ordinary micrometer. In this sleeve a plunger is provided.

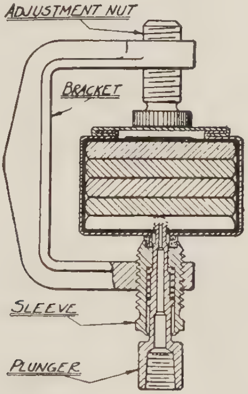


Fig. 23. Spring Lubricating Tool Showing Spring and Tool in Part Sectional View

When preparing to lubricate the springs with this tool, first place a jack under the car frame but not under the car axle. Lifting on the jack in this position will permit the spring leaves to separate, owing to the weight of the axle on them. The proper lubricant to use is a 40 to 50 per cent graphite lubricant. This lubricant may be formed by adding 40 to 50 per cent graphite by weight to a quantity of No. 2½ cup grease.

When assembling the clamp lubricator to the spring, first set the adjustment nut so that the distance between it and the sleeve is a little greater than the thickness of the spring at the point where the hole is located. Place the bracket over the spring and push the threaded end of the plunger through the sleeve and into the $\frac{3}{16}$-inch hole in the metal cover, forcing the canvas against the spring leaf. By screwing the plunger to the right, it will thread its way through the canvas. Next, screw the sleeve against the bottom of the cover so that the bracket is held firmly in that position. The open end of the plunger has a standard $\frac{1}{8}$-inch pipe thread to take a grease gun connection. The grease gun should be used with a flexible connection so that no pressure is used directly against the lubricator plunger.

When forcing the grease in, operate the grease gun slowly so as to allow the lubricant time to spread along the spring leaves between the canvas and the edges of the leaves. If too much pressure is used, it will force the grease out between the laps of the spring cover. The operation is to be continued until some of the lubricant is seen to be forced out at either end of the metal cover.

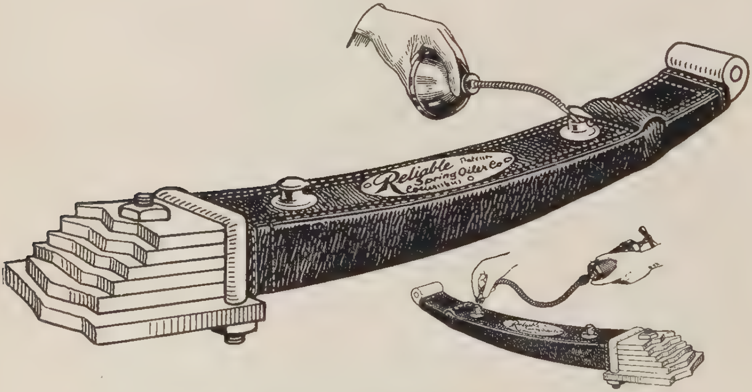


Fig. 24. Fabric Spring Cover

When the lubricating tool is removed, some grease will be forced out through the hole made in the canvas when the tool was applied. This release of pressure will equalize the pressure within the cover so that no more grease will flow. After the flow has stopped, a clean rag should be used to remove any excess grease from the outside cover to prevent an accumulation of dust and dirt on the cover.

Fabric Spring Covers. Fabric spring covers, tailored to fit the spring ends, as shown in Fig. 24, are frequently supplied as standard equipment by the car manufacturer. They may be made up so as to slip over the spring from the ends or may be designed to lace on from the bottom of the spring. Usually some method of lubrication is provided as shown in Fig. 24, the upper view of which shows oil being supplied through the cover to the lubricating hole, the bottom one showing the pressure gun being used for the same purposes. In some instances, these covers are made from rubber after the fashion of an inner tube and are stripped on by stretching the rubber, applying the spring cover from the end. No seam or joint is provided.

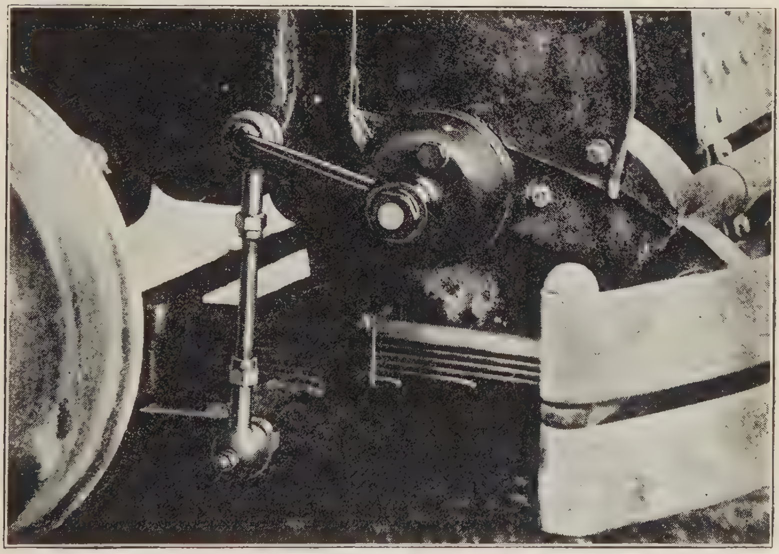


Fig. 25. Gabriel Triple Hydraulic Spring Control

SHOCK ABSORBERS

Ease of Riding Is Standardized. After many long years of individual thought and effort the springs of cars have been brought to a point where designs are quite similar in many instances. The actual details of design may vary quite a bit but the underlying principles are quite similar.

For instance, balloon tires are standard equipment. Cars are no longer equipped with tires of extreme size, as originally. Springs are quite flexible, more and thinner leaves being the general practice. Between the balloon tire and the more flexible spring, a definite need for spring control was created. After many years of experimentation with all types of control units, the best engineering thought today seems to have concentrated itself upon some form or other of hydraulic check. So we have the three units which make for ease of riding common to most cars, namely, balloon tires, flexible springs, and hydraulic spring control devices.

The principle of the hydraulic check is rather simple. A fluid is introduced in a housing, Figs. 25 and 26, which has an internal mechanism so designed that as the spring action occurs, the fluid must be forced through a calibrated hole. It is a well-known fact that fluid resists rapid flow through a small opening and is non-compressible. In a few words, the element of time is taken advantage of through a hydraulic arrangement. The fact that this short interval of time is required to force the fluid through the calibrated opening accounts for the delayed spring action and thus bumps in the road are smoothed out.

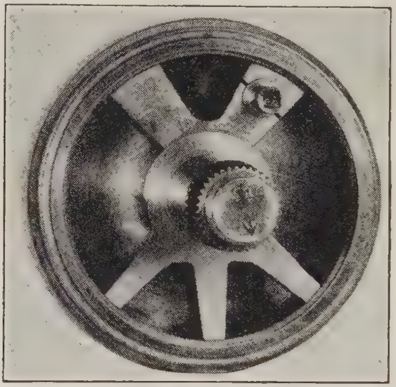


Fig. 26. Internal Construction of the Gabriel Hydraulic Check

Gabriel Hydraulic Shock Absorber. The Gabriel triple hydraulic spring control is built around a sturdy cylindrical case, as will be seen in the illustration, Fig. 27. This case is attached to the car and the movable vane shaft is attached to the axle. Within the cylindrical case there is a segment, Fig. 26, with a movable adjusting screw to control an orifice or calibrated opening. This regulates the pressure for the control of the spring recoil. Another fixed orifice is provided and this one controls the impact or downward stroke of the automobile spring.

The triple hydraulic principle provides multiple paddles acting as a series of dams to create and gain resistance. By having the three vanes within the fixed container and by having these vanes rotate rapidly in either direction, according to the movement of the car axle, a high degree of resistance is secured. Pressure is built up in

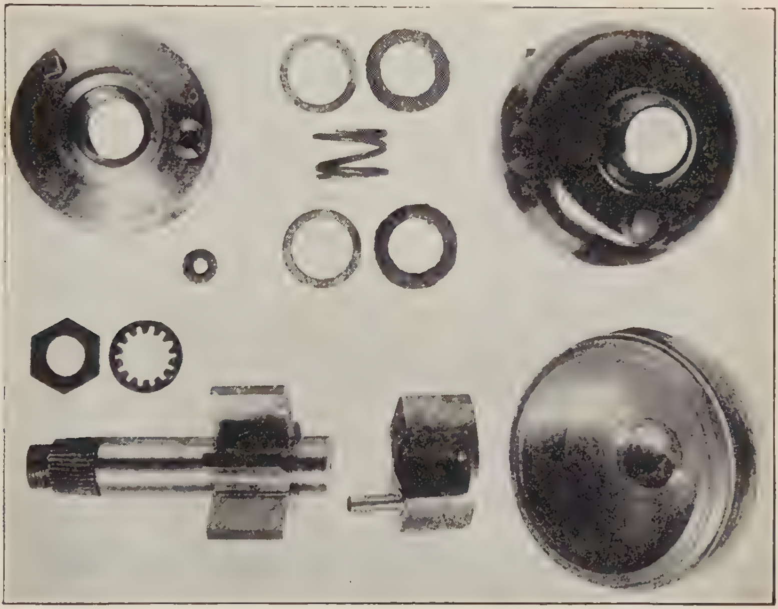
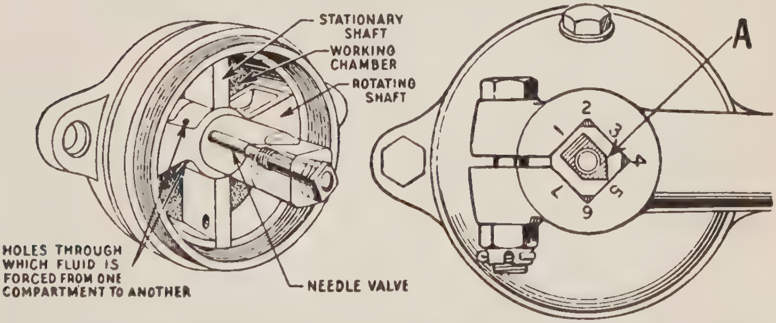


Fig. 27. The Gabriel Triple Hydraulic Spring Control Disassembled


STATIONARY SHAFT
WORKING CHAMBER
ROTATING SHAFT
HOLES THROUGH WHICH FLUID IS FORCED FROM ONE COMPARTMENT TO ANOTHER
NEEDLE VALVE
A
1
2
3
4
5
6
7
Fig. 28. Ford Model "A" Houdaille Hydraulic Shock Absorber and Adjustment Feature

proportion to the impact or recoil encountered. This, of course, being dependent upon the speed at which the car is operated over any road and the number of irregularities encountered.

Servicing the Ford Hydraulic Shock Absorbers. In some of the older cars the devices were equipped with a small indicator on the end of the shaft, similar to that shown at *A* in Fig. 28. For summer months the average setting is 5 for the fronts and 6 for the rears. During colder weather the best adjustment is 2 to 3 for the fronts and 3 to 4 for the rears. The speed of the car must be taken into consideration and the nature of the roadway. The higher the speed the higher the setting.

Some of the later models do not have this indicator on the end of the shaft but the method of adjusting them is the same. In case no numbers show on the absorbers, the average adjustment for the rears, during warm weather, should be made by turning the needle valve to the right until it seats and then backing it off a quarter-turn. In the case of the fronts, back off three-eighths of a turn. If these approximate settings do not give the desired results, they may be changed as needs indicate.

If the simple adjustments indicated do not give the desired results, then it will be necessary to check the level of the fluid in the reservoir and bring it up to the level of the filler plug opening. The fluid may be purchased from the dealer or commercial glycerine may be used. The level of the fluid should be checked each 5,000 to 10,000 miles. If this does not cure the trouble, the service man will remove the shock absorbers and put a check on them which will indicate the trouble. Keep the shock absorber connecting links well lubricated. Spring covers on the car also help to insure easy riding.

Oldsmobile Knee-Action Shock Absorber and Arm. As the shock-absorber arm moves downward due to car spring rebound movement, the fluid pressure opens the rebound relief valve by compressing the valve spring which limits the maximum rebound resistance of the shock absorber. At the same time the compression intake valve opens, due to the partial vacuum created in the compression cylinder, filling the compression cylinder with fluid. As the shock-absorber arm moves upward slowly, fluid is forced through the compression relief-valve orifice to the fluid reservoir. During this operation fluid flows through the rebound intake valve to the rebound cylinder. The size of the relief-valve orifice controls the amount of fluid flow. For rapid arm movement sufficient fluid pressure is built up in the compression cylinder to lift the compression relief valve from its seat by compressing a spring which limits the maximum compression resistance of the absorber. See Fig. 29.

Delco-Lovejoy-Buick Front Shock Absorbers. Hydraulic inertia automatic double-acting shock absorbers, with the upper control arm of the independent front wheel suspension an integral part, are used on Buick cars. Rear shock absorbers are of the double-acting type similar to the front shock absorbers, but without the inertia weight control. The front shock absorbers automatically control the action of the car by means of an inertia valve and a static valve placed in the rebound side of the shock absorber, Fig. 30, so as to operate in conjunction with the main rebound valve. The inertia valve also automatically compensates for changes in temperature, due to the slower or retarded action of the weight in cold weather. This type of shock absorber has a single cylinder and a double-acting piston which controls the rebound when moving in one direction and compression when moving in the other direction. The main rebound and compression valves are located at each end of the piston and are made to operate both as the main control valves and as the inlet valves for filling the cylinder with oil. Oil under pressure from the operating cylinder passes through the main control valves into a chamber of no

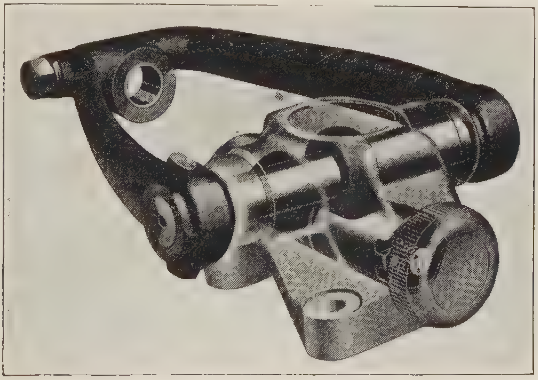


Fig. 29. Front Shock Absorber Used on Oldsmobile Knee-Action Wheels

pressure. On the return stroke, the large inlet valve, which is controlled by a very light spring, opens and allows the oil to flow into and fill the cylinder.

As the car frame and the body travel up, as on rebound, the cylinder farthest from the arm comes into action. The oil in this cylinder is subjected to varying pressures, which is caused by unequal road conditions. This pressure is controlled by three valves, the static valve, the inertia valve, and the main rebound valve. When the car is traveling over smooth roads where there is very little movement to the frame and body, the weight in the inertia valve does not move, and the orifice in this valve is open, thus allowing very little resistance to the oil flow from the cylinder to the reservoir. Under this condition, the static valve, which is located between the cylinder and the inertia valve, is calibrated so as to give just enough control to the car without putting harshness in the ride. This valve is very important to the control of the car on smooth road driving.

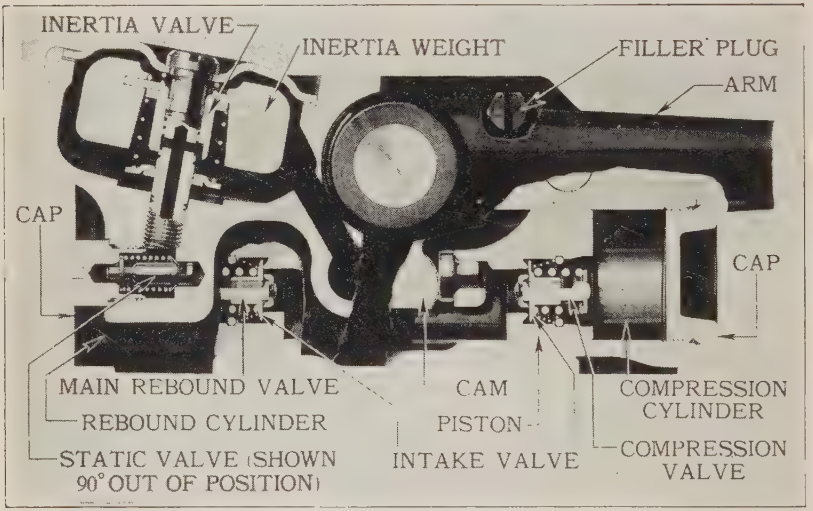


Fig. 30. Delco-Lovejoy-Buick Front Suspension Shock Absorber

When the car is traveling over rough roads, the frame of the car moves down and the lead weight in the inertia valve also moves down, but as the frame moves up on rebound the lead weight, which is supported on a coil spring, does not move up as fast as the frame due to its inertia. This action closes the orifice in the inertia valve which makes the static valve inoperative, and the compressed oil in the cylinder under this condition must pass through the main control valve in the end of the piston. The action of the inertia valve is entirely controlled by nature or contour of the road, and these valves are calibrated to give a smooth, easy ride on smooth roads, with sufficient control for fast driving over rough roads.

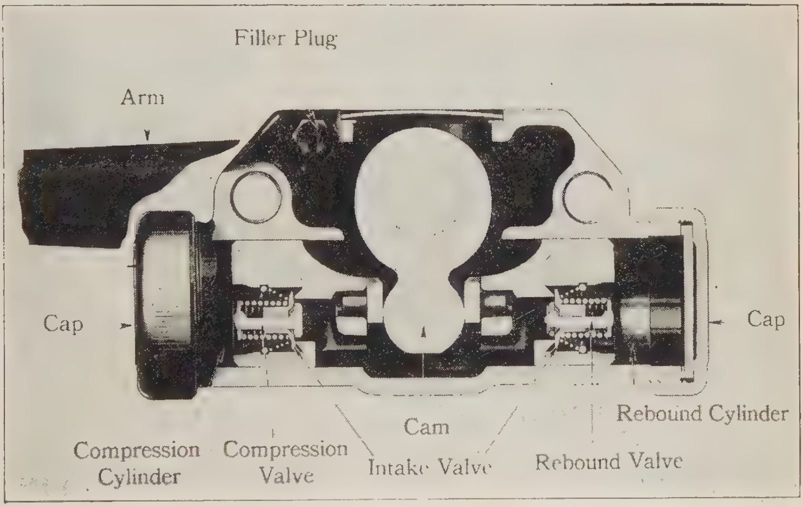


Fig. 31. Delco-Lovejoy-Buick Rear Shock Absorber

Delco-Lovejoy-Buick Rear Shock Absorbers. In the rear shock absorbers, Fig. 31, which are typical of the Delco product fitted to many cars, the rebound and compression valves are located at each end of the piston and are made to act both as main control valves and as inlet valves for filling the cylinder with oil. The action of these valves is similar to those of the main rebound and compression valves, as described for the front shock absorbers.

Delco Shock Absorber Links. The shock absorber links are connected to the absorber arms with composite bushings designed to operate without oiling. A rubber bushing is mounted in the eyes of the shock absorber arms. An oilless bronze bushing is assembled within the rubber bushing and bears on a steel bushing. This steel bushing is firmly clamped between the forked end of the link by a through bolt which prevents relative motion and wear. The lower end of the link passes through a plate which is attached to the axle. Both above and below the plate are rubber and steel washers for insulation.

Delco-Lovejoy Single-Action Shock Absorbers. Fig. 32 shows the normal, at rest, position of the parts of the shock absorber. The relief and intake valves are both closed. A strong piston spring operating beneath the piston eliminates all chances for "clicking" and "lost motion" by keeping the piston against the cam at all times. The rigid link rod provides a positive transmission of all car spring rebound and compression movements to the absorber. Fig. 33 shows the position of the shock absorber parts during a small or slow rebound movement of the car springs. The shock absorber moves slowly upward which allows the absorber arm to move downward in relation to the absorber. The movement of the arm is transmitted through the arm to the piston. A resulting oil pressure created below the piston forces oil through the relief valve orifice to the oil reservoir. This insures an easy and smooth ride that is not affected by pavement irregularities.

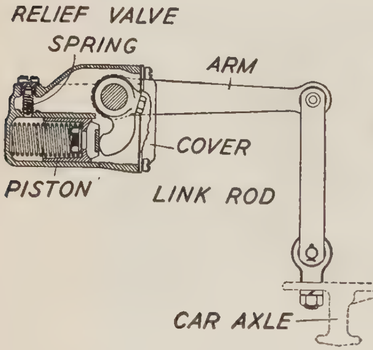


Fig. 32. Shock Absorber at Rest Position

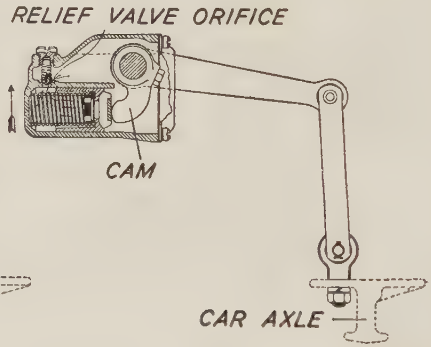


Fig. 33. Position of Shock Absorber Parts or Slow Rebound Movement

Fig. 34 shows the position of the shock absorber valves and parts during a quick or severe rebound movement of the car springs. The absorber, which is fastened to the car frame, moves quickly upward which transmits an equally quick motion to the arm, cam, and piston. The high oil pressure created beneath the piston cannot be dissipated through the relief valve orifice quickly enough so the relief valve raises from its seat by compressing the relief valve spring. The oil then passes through the opening to the oil reservoir.

The maximum resistance of the absorber is controlled by the strength of the relief valve spring. The strength of this spring is predetermined for each automobile only after exhaustive research by shock absorber engineers and car manufacturers. In cold weather when the oil is heavier, the maximum oil pressure is naturally built up sooner and the relief valve opens earlier and wider—automatically taking care of any changes in oil viscosity due to a drop in temperature, without any changes in valve adjustment.

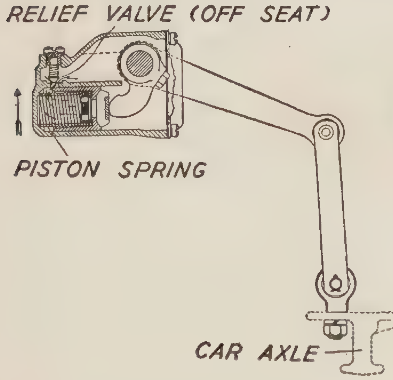


Fig. 34. Position of Shock Absorber Parts During a Severe Rebound

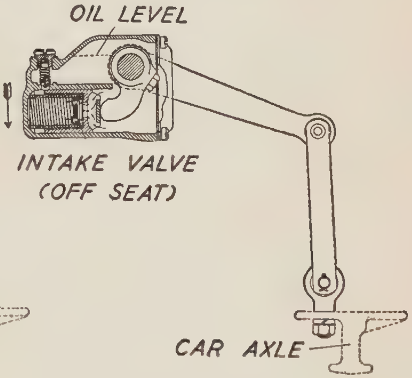


Fig. 35. Operation of the Shock Absorber Parts After a Rebound Movement

Fig. 35 shows the operation of the shock absorber parts after a car spring rebound movement. The absorber and car body move downward causing the absorber arm to move upward in relation to the shock absorber. The cam then allows the piston spring to force the piston upward thus creating a partial vacuum below. The pressure in the oil reservoir then opens the intake valve which allows another charge of oil to flow below the piston in preparation for another rebound movement.

Service Instructions. Before touching the absorbers on a complaint of hard riding, the car springs should be well lubricated and the spring shackle bolts well lubricated. The spring shackles must act freely. The tire pressure should not exceed that recommended by car manufacturers in their specification.

A complaint of noise may occur from a loose installation or within the absorber itself. When checking for noise, make certain that the absorber is bolted tightly to the frame. See that the arm is not striking the fender brace nor rubbing on the steering apparatus, or striking floor boards or gas lines, etc. Also make sure that link rod anchor brackets are tight on the axle. Check the spring shackles for side play. After these points have been checked and it has been determined that the absorbers are noisy, they should then be taken to the nearest authorized shock absorber service station, where they can be properly serviced.

All Delco-Lovejoy shock absorbers are filled with oil and sealed, before they are shipped. The oil used has a very low viscosity and temperature changes will have little effect on the fluidity of the oil. This oil should always be used and it can be obtained from any authorized Lovejoy shock absorber service station or United Motors Service branch.

All the cork arm packing washers used on Delco-Lovejoy shock absorbers are soaked in soft soap before being used in order to counteract oil leaks and packing washer noise. Any actual oil leak will cause a shortage of oil in the absorber which can be determined by disconnecting the link rod from the car axle and pulling down the absorber arm. If the arm goes down easily a part of the stroke, then comes to a stop and goes down slowly the rest of the way, there is not enough oil in the absorber and should be replenished by removing the entire relief valve and filling with the recommended shock absorber oil. Any time the absorbers are replenished with oil, extreme care should be exercised so as not to allow any foreign matter or grit to get into the absorber.

The link rods provide a positive transmission of all car spring and car axle movements to the shock absorber. All link joints are fitted with special bearings and high-grade rubber bushings. The car name, model, and serial number together with the position (front or rear) must be given when ordering replacement parts. The link rod anchoring bracket varies in detail on various installations, but must in all cases be tightly clamped to the axle to prevent slipping and possible interference with the steering or brake mechanism.

The proper combination of relief valves and springs for the best ride is determined after extensive tests by engineers driving the various makes and models of cars over all kinds of roads. The relief valve and spring combination in the absorber, when shipped from the factory, is the best combination for general use and should not be changed.

Delco Direct=Acting Shock Absorbers. The service operations necessary to maintain riding comfort and efficiency from the Delco direct-acting shock absorbers, are as follows: They should be refilled with Delco fluid every 10,000 miles, the rubber bushings top and bottom should be replaced when worn, and the seal assembly around the piston rod must be renewed occasionally. Do not attempt to refill or perform any service operation on Delco direct-acting shock absorbers without special tools. These tools are available, at a very nominal cost, from United Motors branches.

To refill direct-acting shock absorbers, first, remove the absorber from the car and clean away all dirt around the filler plug. Fig. 36 shows the position of the filler plug when the shock absorber is mounted on the car. Pull out the shock absorber to a fully extended position and remove the filler plug, using filler plug wrench 518, as shown in Fig. 37. Pump the piston back and forth until the absorber is completely emptied of fluid. Use a drain pan, as shown in Fig. 38. Have the drain hole down.

Clamp the fluid plug base end in a vise, as shown in Fig. 39, with the filler hole up. Do not clamp on the tubing. Be sure the absorber is in a horizontal position or on a slant, as illustrated. Collapse to the shortest length. Screw the special filling cup 494 into the filler hole, using adapter 495 if necessary, as shown in Fig. 40. Measure the collapsed length of the absorber. Refer to the chart, Fig. 41, to determine the exact amount of fluid to use. Extend the special filling cup to markings in ounces on the filling cup corresponding to the collapsed length of the absorber. Fill the fluid cup to capacity with fresh Delco fluid.

Pull out the absorber to the fully extended position. This will suck part of the fluid into the absorber. Work the piston back and forth, using short quick strokes, until all the fluid is worked into the absorber. Replace the filler plug, using a new filler plug gasket. Stand the absorber up in the vise, as mounted on the car, moving the unit up and down to expel any possible air pockets, and remount the absorbers on the car. A word of caution is given here. Be sure the absorber is completely emptied of all fluid when draining. Use only Delco fluid in the exact quantities as specified in Fig. 41 when refilling. The absorber will be damaged if filled with an excessive quantity of fluid. Use only the special filling cup 494. Do not use a fluid gun.

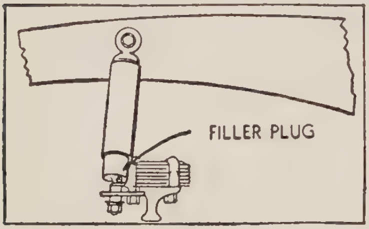


Fig. 36. Shows Position of the Filler Plug When Shock Absorber Is Mounted on Car

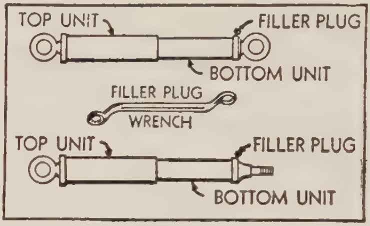


Fig. 37. Removing Filler Plug

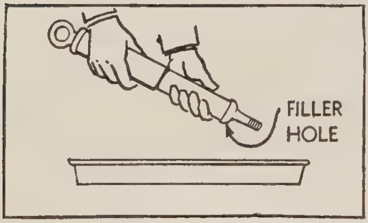


Fig. 38. Drain Pan

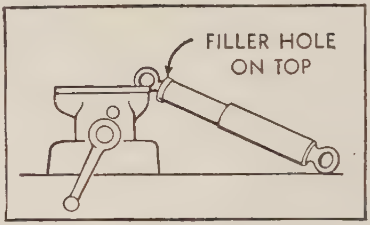


Fig. 39. Holding the Fluid Plug Base

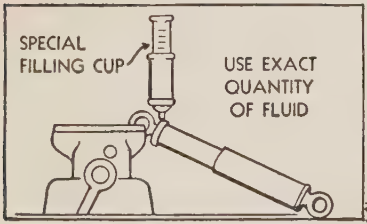


Fig. 40. Mounting Filler Cup

COLLAPSED LENGTH

Length	Fluid Capacity	Length	Fluid Capacity
$8\frac{7}{16}''$—	$4\frac{3}{4}$ oz.	$9\frac{15}{16}''$—	$5\frac{1}{4}$ oz.
$9\frac{7}{16}''$—	5 oz.	$10\frac{7}{16}''$—	$5\frac{1}{2}$ oz.

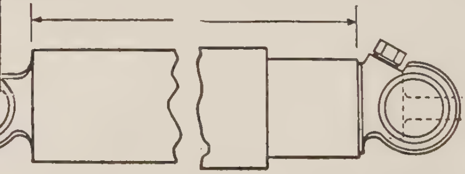


Fig. 41. Determining the Amount of Fluid Required

SWAY BARS AND STABILIZERS

Sway Bar. Chrysler Airflow models make use of the sway bar illustrated in Fig. 42. This particular bar is connected by means of the two links to the frame side members. The lower ends of the bar are attached to the front axle beam in such manner that they move up and down with it.

The tendency of an automobile to roll when rounding a turn at high speed, is well known. In order for the front end of the Chrysler Airflow to roll, it would be necessary that the bar be twisted; otherwise the deflection of the springs will be approximately equal. The resistance of the bar to twisting, serves to keep the front end of the car on an even keel when rounding curves.

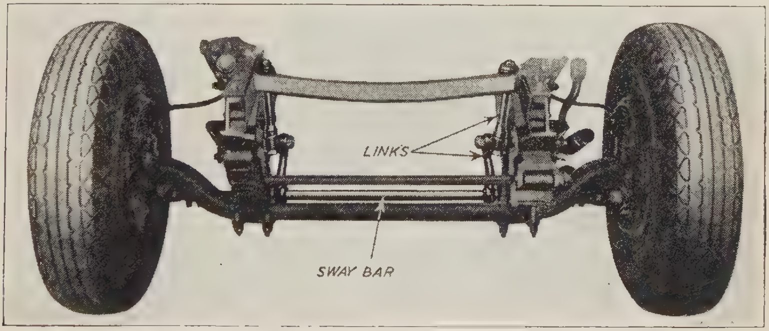


Fig. 42. Stabilizer or Sway Bar on Chrysler Airflow Front Axle

The Plymouth, Dodge and certain other models produced by Chrysler, make use of a similar device. In any case, the purpose is the same and the general principle of operation quite similar to the one described.

Stabilizer. Devices similar to the one illustrated in Fig. 43 may be termed sway bars or stabilizers. They may be mounted on either the front or the rear of the automobile, some engineers preferring one method and some the other. In many instances, the stabilizer is mounted in conjunction with the rear shock absorber arms. In other instances, as shown in Fig. 43, the shock absorber arm mounting bracket is extended to receive the stabilizer linkage connecting the car frame with the stabilizer arms. The use of softer springs and independent front wheel suspension promotes a tendency for the car to roll or sway outward on turns. Cars equipped with the stabilizer must needs set up a twisting movement in the stabilizer bar to permit rolling of the car frame and body. The steel of the stabilizer bar resists this twisting movement to the end that the spring on the side of the car on the inside of the curve must be depressed in amounts approximately equal to that of the spring on the outside of the curve, thus causing the car to travel more nearly in a normal position when rounding curves or driving with a cross wind.

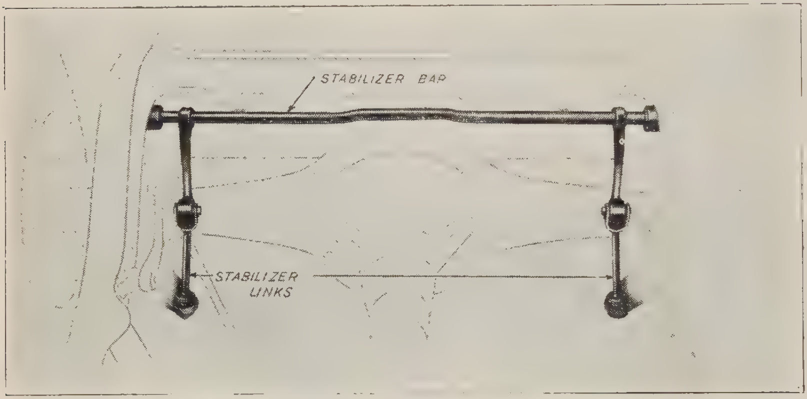


Fig. 43. Stabilizer Mounted at Rear of Car Frame

WHEELS

Beyond a doubt the history of the development of the human race is more closely tied up with the development of the wheel and various applications of wheels than with any other mechanical unit with which we are familiar. The development of the wheel is most interesting.

Early automobiles made use of wheels very similar to those used for buggies and other horse-drawn vehicles. Very shortly it was discovered that this type of wheel was not exactly suited to the needs of the automobile and ever since the original inception of the automobile as a practical means of transportation of people and freight, the tendency has been toward decreasing the diameter of the wheel and increasing the diamter of the cross section of the tire. The results are that the wheels and tires in use today are something almost undreamed of at the original inception of the automotive engine and car as a means of transportation.

Wheel Sizes. In the early years of automobile design, the wheels were as much as forty inches in diameter. Shortly they were reduced to thirty-six inches, thirty-four inches, and presently they were cut down to thirty inches as the standard for the outside diameter of wheel and tire. As car speeds have increased along with the general demand for speed and good roads, the wheel diameter has been lowered time and again.

Instead of speaking of the outside diameter of the tire as the wheel size, the usual practice is to speak of the diameter of the rim or wheel itself, so that today we have twenty-inch wheels, eighteen-inch wheels, seventeen-inch wheels, and even sixteen-inch wheels in use in connection with balloon tires.

Tires are indicated in sizes for various wheels. For instance, we may have a tire which is 6.50-18, meaning that it is a 6½-inch tire for an 18-inch wheel.

Bus and truck tires too have steadily been decreased in diameter and increased in cross section so that the wheel has been reduced in size. At times, especially on the heavy duty trucks and busses, it is not unusual to find the brake drum as large as the wheel itself.

PASSENGER CAR WHEELS

Wood Wheels. The wood wheel has been commonly termed the artillery type wheel. This type of wheel has proven definitely satisfactory for use on passenger cars. Doubtless more cars have been fitted with this type wheel than all other types combined. Along with the tendency in all departments of automobile manufacturing to get away from the use of wood has come the development of the welded-steel spoke wheel (resembling a wire wheel), the general adoption of the wire wheels, and the increased use of disc wheels.

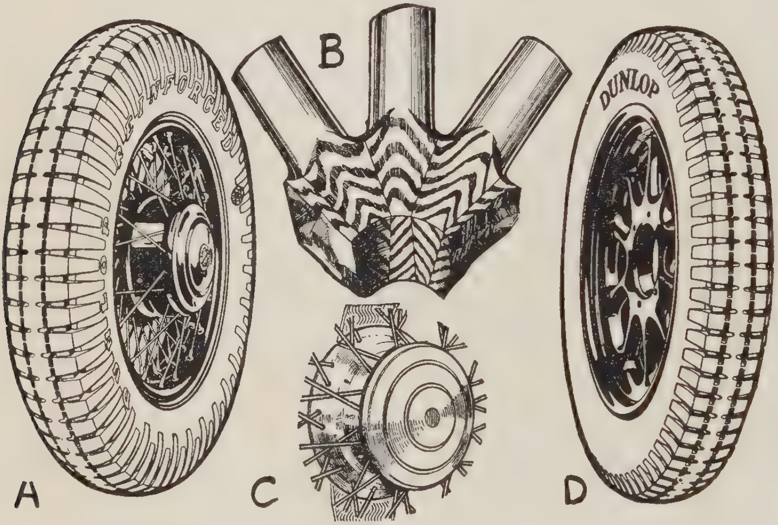


Fig. 1. *A*—Wire Wheel with Large Hub Which Encloses the Holding Stud Nut
B—Section of a Wood Spoke Wheel Having Tapered Joints for the Inner Ends
C—The Large Plate Enclosing the Wire Wheel Hub
D—An Artillery Type Wheel Made from Metal—an English Development

Styles in wheels change much after the fashion of styles in other elements of automobile design. There is little to choose between the relative merits of the several types of wheels, which are illustrated in Figs. 1, 2, 3, and 4.

The wood wheel is built from hickory, as a rule. For many years the wood felloe was also made of hickory, but present-day practice makes use of wood for the spokes only. The method of assembling the spokes is illustrated at *B*, Fig. 1. The outer ends of the spokes are fitted to the steel felloe with a round tenon. The inner ends are fitted together either in the fashion shown at *B* or with a straight cross section. The one shown at *B* is so designed that by tightening up on the hub bolts, the wedging action of the spokes will throw a pressure on them and set them tight, one against the other.

Care of Wood Wheels. Wood wheels should be painted and the paint maintained in good condition in order to exclude moisture and at the same time prevent drying out. The objection to the moisture is swelling, which creates pressure, which is later reduced as the wheel dries and cracks are formed. Since the inner ends of the wheel spokes rest on the hub and since the strength of the wheel is dependent upon the hub and the hub flange plate being drawn tight so as to hold the spokes rigidly, it is important that the wheels be gone over at least once a season to see that the hub bolts, as indicated at *A*, Fig. 3, are tight. In order to tighten them, it is necessary to remove the wheel and use a wrench from the inside. The nuts on the hub bolts are prevented from turning off by battering or riveting the inner ends of the bolts. While it is possible to tighten the bolts by drawing on the nuts, it is not an easy

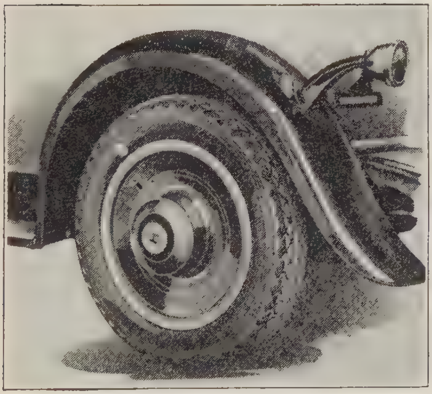


Fig. 2. Disc Type Wheel with Large Hub Enclosing the Holding Stud Nut

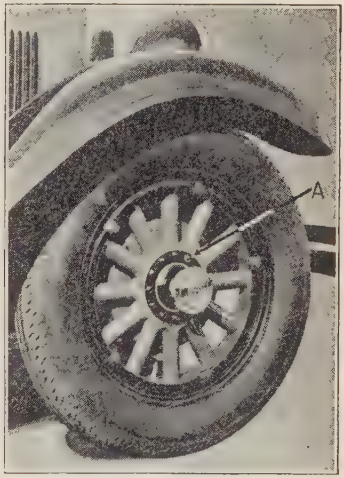


Fig. 3. Artillery Type Wheel Having Exposed Hub Bolt Heads

matter to remove the nuts since the battered condition of the bolt prevents this. If necessary to remove the nuts, use a chisel and split them, throw away the bolts and install new bolts and nuts and, after drawing them tight, rivet over the ends of the bolts again.

When the wood type artillery wheel has become misaligned, owing to an accident, it is often possible to straighten it by means of loosening the hub bolts a trifle, inserting shims at the proper points, and then tightening them again. Tire wear is rapid in case of a misaligned wheel.

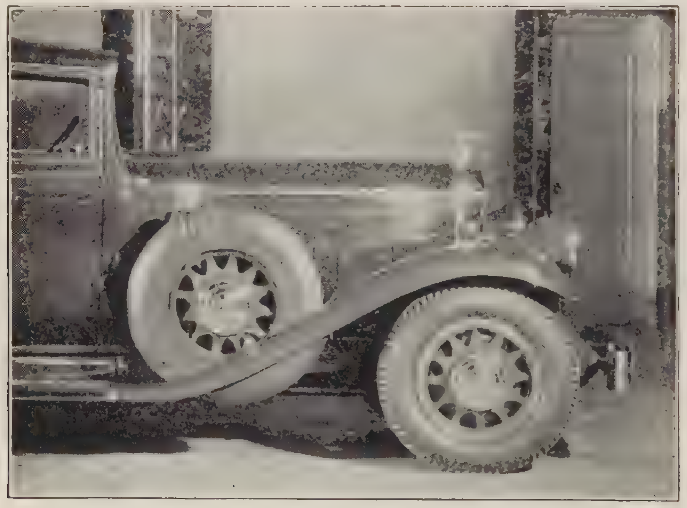


Fig. 4. Artillery Type Hollow Metal Spoke Wheels

When the wood wheels have dried out for any reason and are squeaking, it is possible to tighten them by driving a plug between the ends of the spokes and forcing them outward or making use of a device to tighten the felloe against the outer end of the spoke. Wedges between the inner ends of the spokes are sometimes used to tighten the spokes, one against the other in the hubs of the wheels.

Wire Wheels. One of the serious objections to the use of wire wheels on early makes of automobiles was the difficulty experienced in removing or replacing them. It sometimes happened that the hub nut would become stuck, with the result that it was practically impossible to remove the wheel.

This led to the adoption of the hub with a large flange at the rear, through which the studs attached to the wheel hub, which is fitted to the spindle, were projected and on which nuts were run to lock the wheel hub to the spindle hub. The chief objection to this construction was the unsightliness of the assembly unit. This resulted in the adoption of the type of wheel shown at *A*, Fig. 1, where a large hub is used and in which the holding nut and stud are arranged. The plate over the hub is removed by means of a screwdriver and this exposes to view the holding nuts, which are then removed by means of a wheel or rim wrench. The same general construction is made use of with reference to the disc wheel assembly, as shown in Fig. 2.

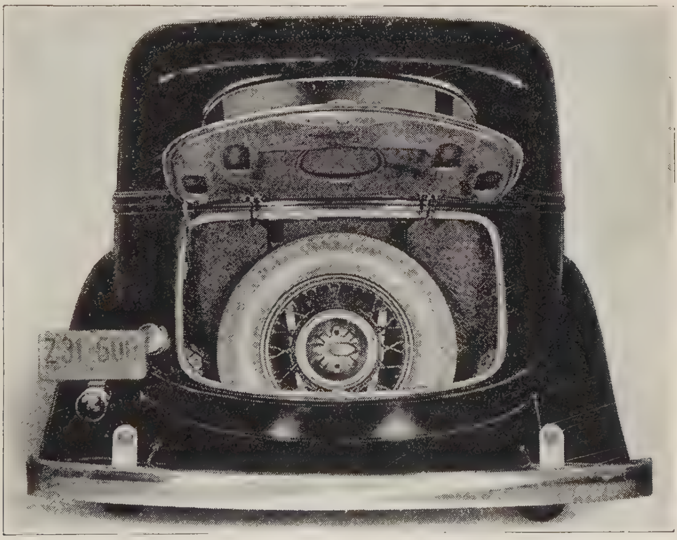


Fig. 5. Essex Spare Wheel

The use of the large hub, Fig. 5, has resulted in shortening the spokes of the wire wheel and in the use of heavier spokes, made possible by the fact that the size of the hub being increased allows for larger units on the inner end of the spokes.

Wire Wheel Troubles. The spokes of a wire wheel should be inspected frequently as they work loose in service. This not only causes a creaking noise but will also cause the nipples of the spokes to work loose in the hub or rim and pull out of position, which will cause the wheel to run out of true. Loose spokes also weaken the wheel and if allowed to get very bad might be the cause of the wheel collapsing. The wheel should be painted as soon as there is any sign of the paint chipping off, especially around the nipples of the spokes, as a prevention against rust. The wheels should also be kept running truly and the basis of this is to keep the spokes adjusted and tight.

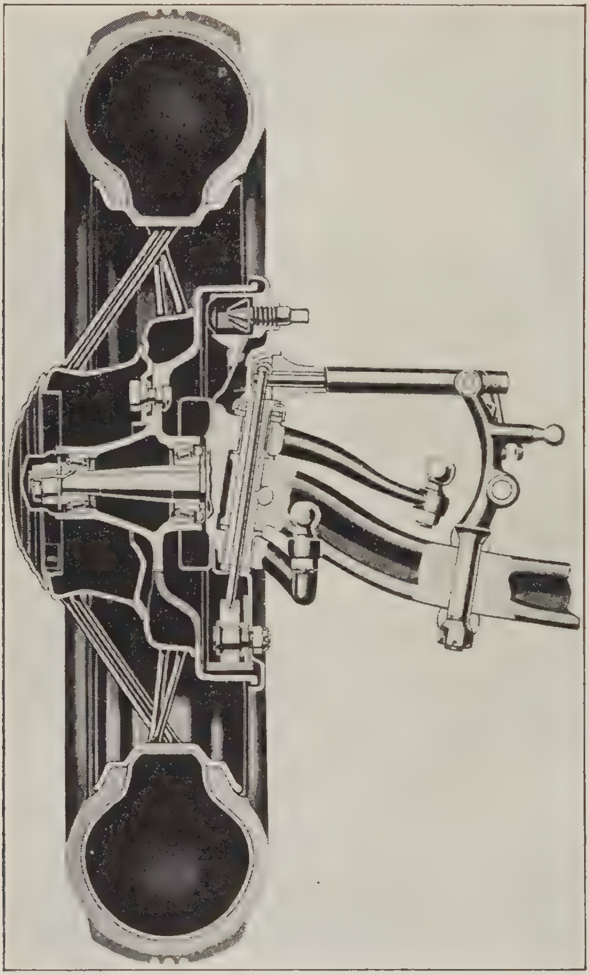


Fig. 6. Sectioned View Ford "V-8" Front Wheel, Brake and Axle Assembly

Welded Steel Spoke Wheels. Most wire wheels are built on the tension plan, that is, the spokes are under tension and have no compression strength. The Ford steel spoke wheel, Fig. 6, which resembles the wire wheel in appearance, is not a wire wheel in the truest sense of the word. The spokes are heavy enough so that they will carry some load as compression members of the assembly. They are so welded to both the hub and the rim that the spokes become an integral part of the assembly.

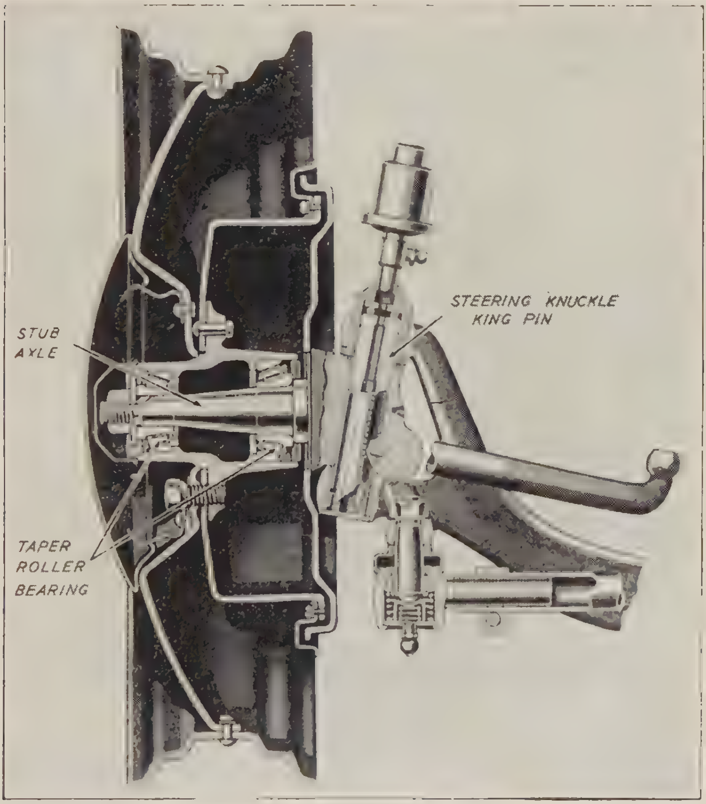


Fig. 7. Terraplane Wheel in Section
Courtesy of Hudson Motor Car Company

The Ford wheel is further improved in that the rim is both felloe and tire mounting. The design is termed drop center or Dunlop design. The part of the wheel which resembles the steel or wood felloe of the ordinary wheel is in reality part of the rim and the tube drops into and utilizes this space. When the tires are dismounted, the beads must enter the drop center for part of the circumference of the wheel in order to allow room to slip the other side of the tire off of the rim or wheel.

The Terraplane wheel is shown in sectional view in Fig. 7.

The Pressed=Steel Disc Wheel. Fig. 8 illustrates the Buick wheel. It will be noted that this wheel is given the appearance of an artillery-type wheel. The spokes are very short and the appearance given is more of a decorative feature than a useful one. This wheel is of the drop-center type and carries a 7.00-16 tire.

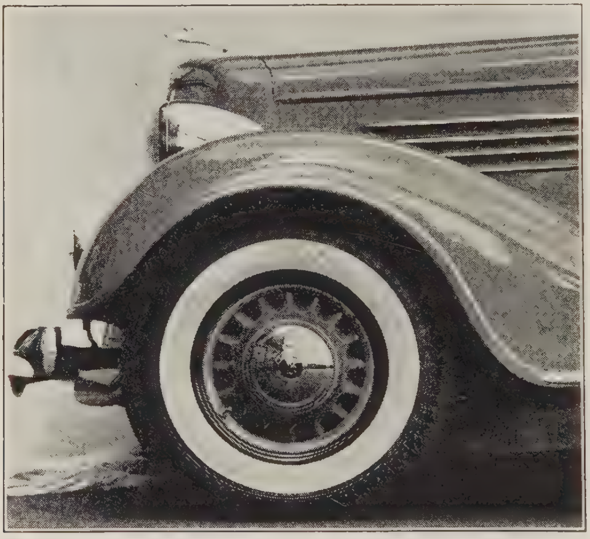


Fig. 8. Artillery-Type Pressed-Steel Wheel

Servicing Disc Type Wheel. When a car equipped with disc type wheels has been in a serious side skid or accident, the discs are likely to have been sprung so that the wheel no longer turns true. This condition may be remedied by having the wheel removed and clamped in a machine designed for straightening disc wheels. The art of straightening a disc wheel is one requiring considerable skill and patience. The usual result of an attempt to straighten them is finding that while one part has been straightened, another part has gone out of alignment. However, with care, the job may be successfully performed unless of course the injury is too extensive. When doing this work, it is absolutely necessary that some form of indicator be set up to show how the work is proceeding. This indicator may be on a rod in the center of the wheel hub, so that it may be rotated around the diameter of the wheel to indicate the relative position of sections of the wheel and rim. Disc wheels which have been sprung quite badly in an accident should be discarded in favor of new wheels.

Bus Wheels. Figs. 9 and 10 illustrate disc wheels designed for bus service. It will be noticed that they are quite small in comparison to their width. In Fig. 9 the section at *A* shows the wheel and rim assembled, while the view at *B* shows the rim *B* removed from the wheel *C*. These wheels are so designed that the section *C* has the drum portion of the wheel extending outward beyond the rim. This construction permits of bolting two of these wheels together to form a dual construction, Fig. 10. It will be noted that the rim of the outer wheel extends away from the drum of the wheel and the rim of the inner wheel, likewise, so that two tires may be installed side by side without touching each other.

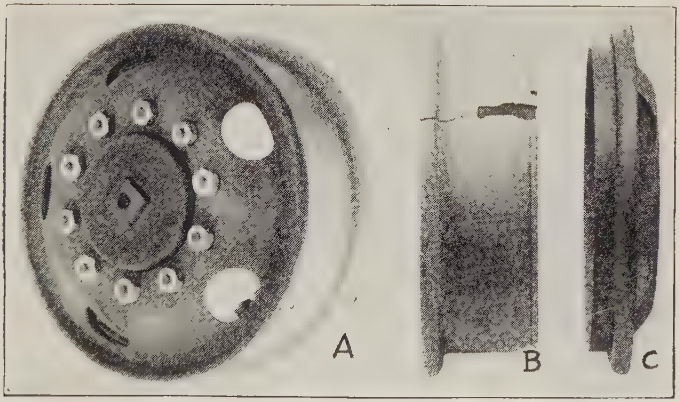


Fig. 9. Single Bus Wheels
A—Assembled; *B*—Rim; *C*—Wheel Disc

Truck Wheels. Truck wheels are oftentimes of the general design of those shown in the case of the Federal Truck, Fig. 11. It will be noted that these wheels are formed from steel stampings, having certain sections stamped out to lighten the construction. The wheels are so designed that it is possible to make use of them for either front or rear, using the same size tire for the single front tire and double tires for the rear, or single tires may be used at the rear if desired. When double tires are used, the portion of the wheel which is out, as shown in Fig. 11, is mated against another and similar one, the two flanges at the center part of the hub being locked tightly together, thus forming a dual wheel similar to that shown in Fig. 10.

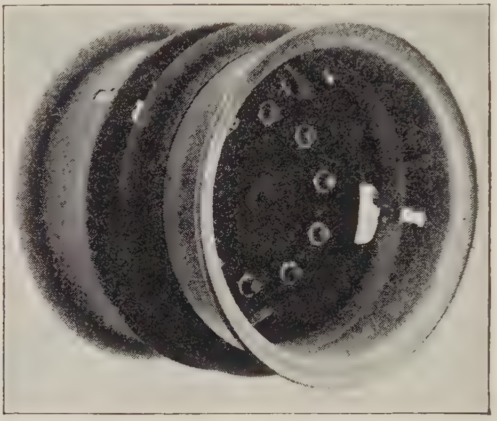


Fig. 10. Dual Bus Wheels and Rims Similar to Those Shown in Fig. 12

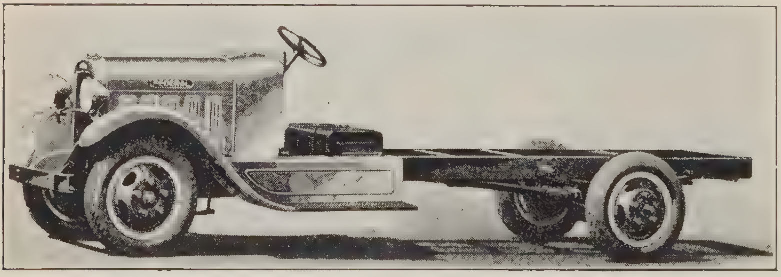


Fig. 11. Pressed Steel Wheels for Truck Use

Cast=Steel Wheels. The heavier the service the more unsuitable do wood wheels become, that is, wood-spoke wheels. For many five-ton trucks, practically all seven- and ten-ton trucks, and nearly all tractors, the cast-steel wheel is used, either spoked or solid, the spoked form being given the preference. Fig. 12 illustrates a truck fitted with spoked cast-steel wheels. The wheels are cast with heavy ribbed spokes, a ribbed felloe, and a grooved-felloe surface, into which the tire is set.

Miscellaneous Wheel Types. Steel wheels are gaining for heavy truck use, and a number of the better steel-casting firms are now getting into this work, with the result that better steel wheels are becoming available.

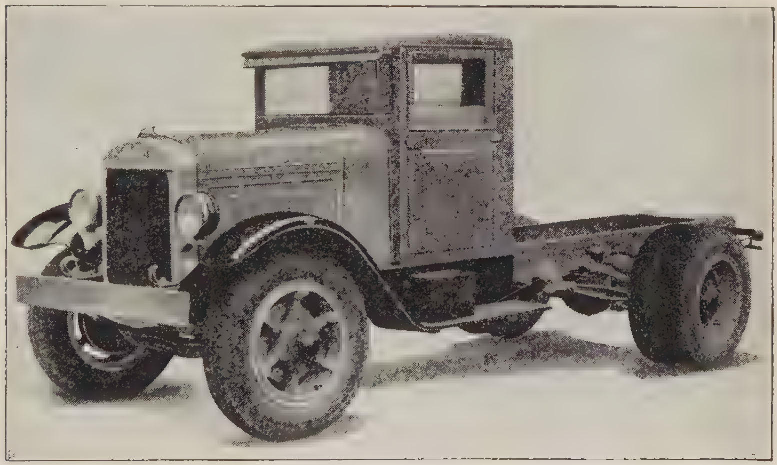


Fig. 12. Stewart Truck Chassis Fitted with Cast Steel Wheels and Dual Tires in Rear

Other constructions, such as steel and wood combination wheels with removable and replaceable spokes, and the like, are rapidly going out of existence. Truck work is unusually severe, and it takes but a few weeks of actual use to show up any of the so-called freak wheels. The simplest seems to be the best, the only question at present being whether the material shall be wood or cast steel. Pressed steel may offer opportunities in combination with welding, as good work has been done on pleasure-car wheels of this type.

SERVICING HINTS ON WHEELS

No matter what construction the wheel may be, it is necessary that the parts be kept bolted together in a tight fashion if bolts are used. The wheel receives a tremendous pounding as the car is driven over the roadway. Keep the bolts tight.

Keep the wheel locked on the rear axle drive shaft.

Keep the wheel locked tight to the wheel hub. In the case of front wheels, keep the wheel hub adjusted properly so as to have the wheel run true.

Wheels should be kept painted. It is not advisable to use a pyroxylin lacquer, since the vibration of the wheel will ordinarily cause it to loosen. It is best to use oil paint.

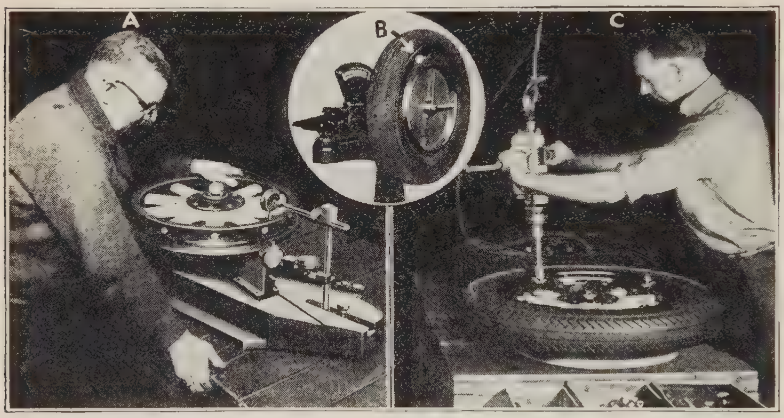


Fig. 13. *A*—Testing Wheels Which Have Been Balanced by Addition of Small Metal Weights
B—Tire Balancing Machine Which Determines Lightest Section of Casing Where Tube Valve Is to Be Used as Counterweight
C—Assembling Balanced Tires on Balanced Wheels at Oakland-Pontiac Factory

When mounting a wheel, make certain that the wheel is mounted straight and true on the hub, otherwise the tire wear will be unduly fast and vibration may be set up.

Balance the wheels so that they are not likely to cause tramping of the front end of the car. If disc wheels are bent, have them straightened.

If artillery type wood wheels dry out, have them shimmed and tightened.

The wire spokes in the wire wheel construction should be kept tight. This may be done by removing the tire and using a spoke wrench on the ends of the wire spokes.

Do not operate an automobile having cracked wood spokes.

Have them replaced with spokes of the same weight. If the spokes should be heavier, wheel shimmy and tramp will be set up.

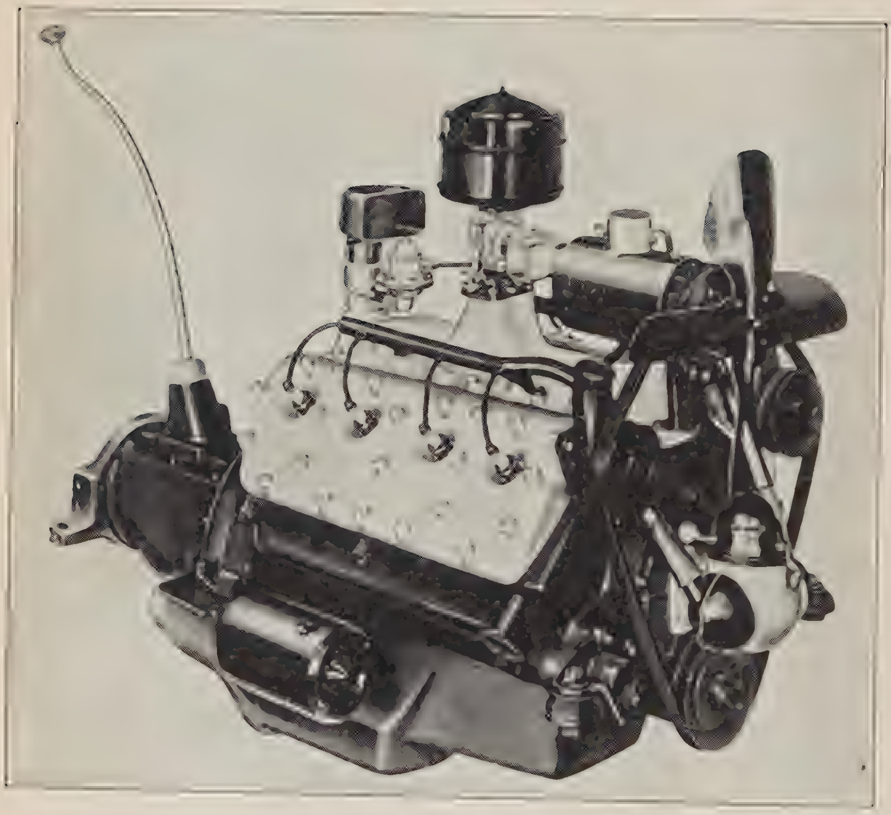
In the case of accident to a welded spoke wheel, it is best to replace the wheel. It is practically impossible to make any major repair on these items.

BALANCING AUTOMOBILE WHEELS

Owing to the fact that the steering of the passenger car is so very sensitive, it was found necessary to balance front wheels, tires, and tubes most carefully. The workman at *A*, Fig. 13, is using a device for checking up on wheels to see whether they are true or whether they will run true both with reference to side wabble and whether the rim is the same distance from the spindle at all points.

If the wheel at *A* is found to be true and in balance, it is passed and is ready for a tire. Before applying a tire, the tire is balanced as shown at *B*. This shows a special scale device which weighs and determines the lightest portion of the casing. This point is then marked.

Having balanced the front wheel and determined the light portion of the tire, the two are then assembled as at *C*, with the tube and the tube valve stem used as a counterweight to balance the light portion of the casing. It is for this reason that all tires are marked with some means to indicate the point at which the tube stem (valve) should be placed. If the person mounting the casing is careless and pays no attention to this mark, it is very likely that the wheel will be so badly out of balance that a severe case of front wheel wabble or tramp may be developed. Tramp is particularly likely to develop in a case of this kind if the car is driven at high speeds with rather low air pressure.



ENGINE FOR FORD "V-8"

TIRES

Tubes. In the early days of inner tube construction, the usual practice was to design the tube in straight rubber-hose-like sections. The ends of the section were cut to length and then brought together and vulcanized to form an endless tube. As the outer diameters of tires were decreased, for instance from 21 inches to 17 inches, and the cross-sectional area of the tire was increased, it was found necessary to mold the tube to the shape of the tire in order to prevent overlapping of the rubber tube and rapid deterioration of the tube itself. The degree to which the tube should be molded, depends to a certain extent upon the size. The greater the difference between its inner diameter and the outer diameter when inflated within the casing, the more imperative the need for full-circle molding.

Standard tubes are made from rubber compounded to the specifications of the tire manufacturer, these varying somewhat for different companies. The standard tubes are usually lighter in construction than special tubes. This is the type of tube supplied by tire manufacturers and sold in great quantities. Following in line, will be found the high-speed tubes, heavy-duty tubes, and other tubes of special design, as for instance, those designed to prevent punctures affecting the air pressure within the tube. In order to effect this type of sealing action, the inner portion of the tube material is usually under compression so that when a nail is forced through the casing and tube, the material surrounding the nail is compressed tightly against it, and as long as it remains so, serves to act as a seal to prevent loss of air at the point of puncture.

While rubber would seem to be without pores and thus resist entirely the loss of air, this is not necessarily the case. Very often a new tube without any apparent defect, permits loss of air. It is necessary to check the air pressure from time to time and see that normal pressure is maintained. Certain manufacturers build tubes from specially compounded materials which resist loss of air through the pores of the tube material to a marked degree. Fig. 1 shows a section of tube within a section of casing. This illustrates a drop-center rim, cut through at the tube-stem point. It will be noted that in this case the tube stem is mounted at an angle. The tube stem shown here is of metallic construction, although the use of rubber in connection with metal for tube stems is common practice also. No outside nut is utilized when rubber is used, inasmuch as the tube then is designed to fit into the hole provided for it on a taper so that, as it is forced outward by the air pressure, it locks against the metal of the rim, thus sealing it against the admission of moisture.

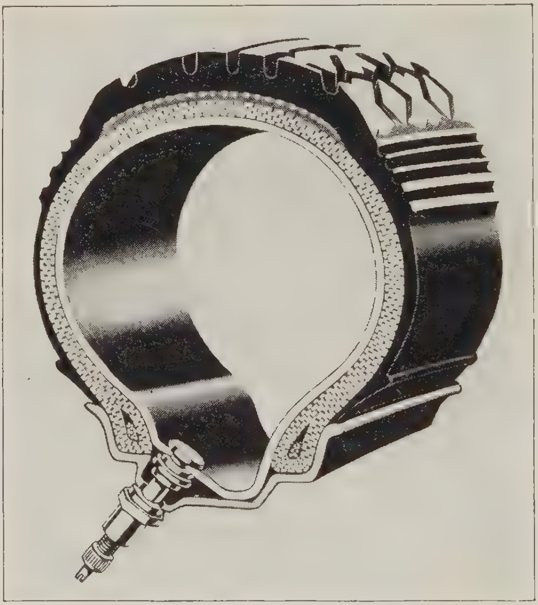


Fig. 1. Section of Tire and Tube on a Drop-Center Rim

Tires. That portion of the automobile tire used to encase the tube, is ordinarily spoken of as the tire, although in many cases it is also referred to as the casing. Fig. 2 illustrates the tire in cross section, with names of the various points in the tire. If these points are in mind, the tire repair man will have less trouble in understanding instructions given for the repair and care of tires.

Plies. The number of plies in the carcass of the tire, Fig. 3, has much to do with the performance of the tire, and determines in no small way the method of speaking of and describing tires.

For instance we have 4-ply tires, 4-ply high-speed and again we have 6-ply tires, 6-ply high-speed or heavy duty, and so on. Usually, in truck work, tires are 6- or 8-ply for light trucks and have more plies for heavy trucks. These tires are commonly known as heavy-duty tires.

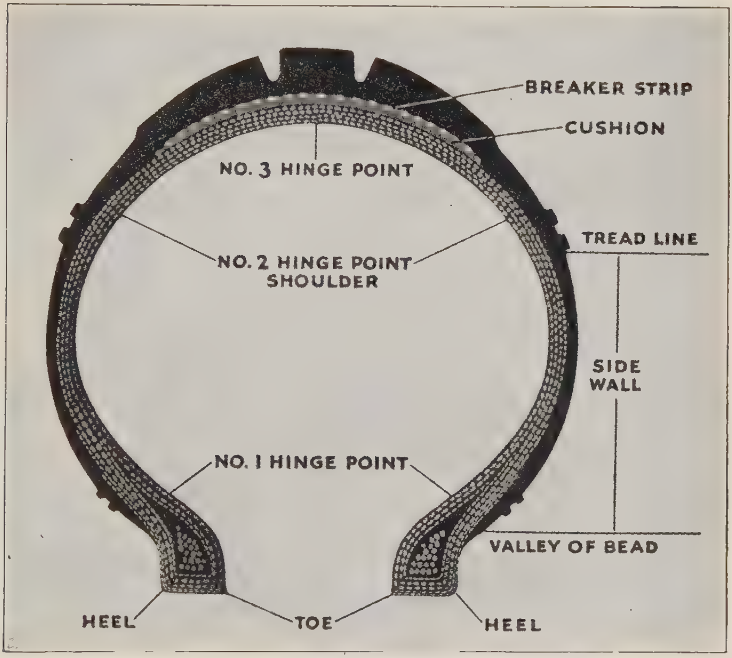


Fig. 2. Cross-Section Illustrating the Various Points of a 4-Ply Balloon Tire

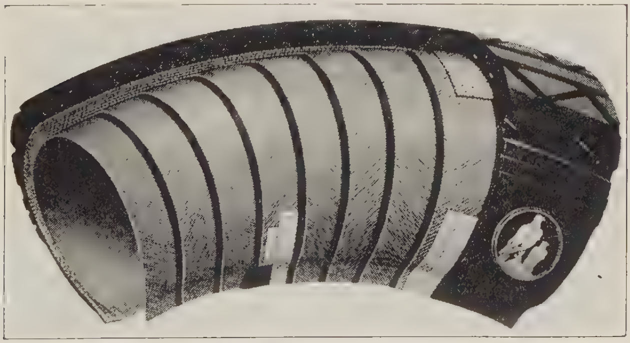


Fig. 3. Cord Construction of a Heavy Duty Tire

The life of the tire is largely dependent upon the load carried, the design of the tire, and the care which is given to it. It is not necessarily true that the heavier the tire, that is the greater the number of plies, the longer the life of the tire. These features must be taken into consideration with the nature of the service the tire is to give. If the tire has too many plies for a light load, the tendency is always one of allowing the pressure to become low, and in this case the heat generated within the carcass of the tire will prove its destruction. Heat is perhaps the greatest enemy of the tire carcass and is generated by the friction of the parts of the tire as they bend or work against each other in the flexing of the tire as it comes into contact with the roadway. This feature is illustrated in Fig. 4, where it will be noted that, as viewed from the ground (or in this case from beneath a heavy section of glass), the impact of the load on the roadway causes a flattening of a considerable section of the tire, which is termed the area of contact. This is further illustrated in Fig. 5, where it will be noted the side walls of the tire are caused to flex severely, as the load is engaged by the section of tire in contact with the roadway. The dotted section of this tire indicates the contour of the tire without load, and the arrows *1* indicate how the tread of the tire comes into contact with the roadway under load. Naturally the tire tread, which is illustrated by the heavy dark section, must be so designed as to support the carcass

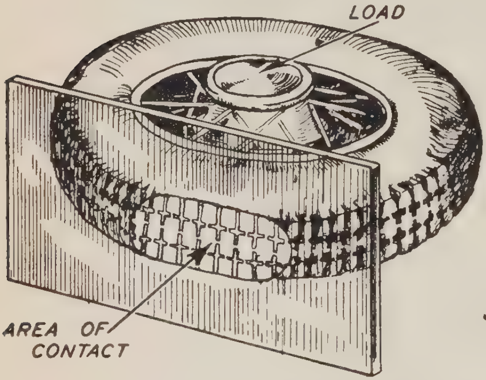


Fig. 4. The Area of Contact Determines the Load-carrying Ability of a Tire

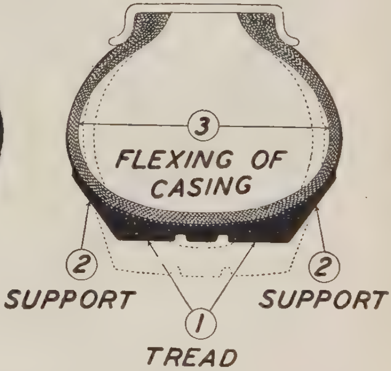


Fig. 5. Flexing of Tire in Road Contact

of the tire to the best possible advantage. This is done in the case of the tire illustrated, by means of the supports indicated by the arrows *2*. Considering the amount of flexing of the casing, it is readily understood that if too much rubber and fabric is utilized in building the tire which is designed to give easy riding, as in the case of a passenger car, then there will be too much heat generated within the casing. It was for this reason that the use of the four-ply tire with large cross section and low inflation pressure became so common.

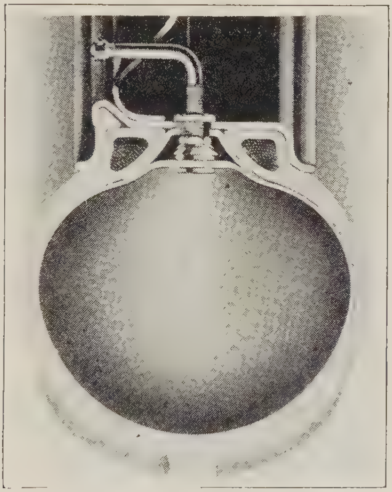


Fig. 6. Section of Tire Showing Cables in Beads

Cables. There is one portion of the tire which is not permitted to flex, bend, or stretch under the load it supports, and that is the cable within the tire bead. These are usually made from steel wire and appear somewhat in the order of those shown in Fig. 1 and again in Fig. 6. It will be noted that the plies of the tire are run around the cables, the cables first being imbedded in a rubber compound to prevent the plies of the tire fabric being cut by them. These cables serve to keep the beads of the tire to exact dimensions, no matter how heavy the load imposed on them, thus preventing the bead coming away from the shoulder of the rim on which the bead rests when the tire has been mounted and the tube inflated. In rare instances, cables do cut through the fabric of the tire and cause destruction of the tire. Naturally, care must be used in mounting and demounting casings, in order to prevent digging into the fabric where it goes over the cable and thus starting an injury which may result in future failure.

Treads. That portion of the tire which is in contact with the roadway is termed the tread. A tread used on a heavy duty tire is shown in Fig. 7. Not all tire manufacturers utilize the same method of tire construction, so that we find some difference in the construction between the tread itself and the cords or plies of the tire. Usually we find the use of cushion stock and a breaker strip, common practice. Some factories utilize two breaker strips, depending upon certain developments, within their own experience, as being more satisfactory for securing long tire life.

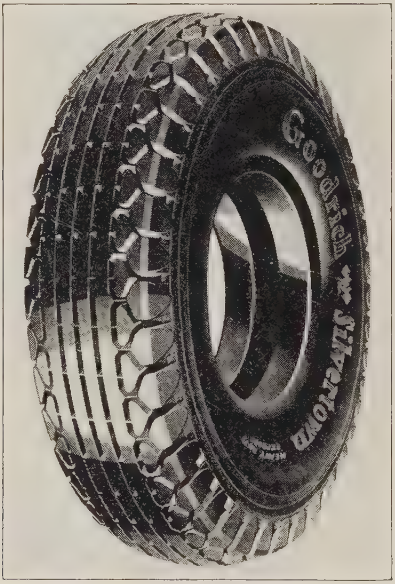


Fig. 7. Tire Tread

After all, granting that the carcass holds up and does not fail prematurely, the length of life of the tire is largely dependent upon the design of the tread and the amount of material placed in it when the tire is built. Compounding of tread materials is an art, and the life of the tire bears a direct relation to the ability of the tread gum, as it is finally finished in vulcanized state, to resist wear over all manner and type of roadway, and under adverse load conditions.

Tire Types. The range of tires is very wide. Aside from the use of pneumatic tires on passenger cars, trucks, and busses, with which everyone is familiar, there is a very wide range of industrial uses with which most are not so familiar. Fig. 8 illustrates a U. S. "Royal" super-balloon tire 16x7.00, which is typical of the production of most larger companies, all of which have designed tires for similar use. Fig. 9 shows the Goodyear "Airwheel" for automobile use. Goodyear also manufactures an "Airwheel" used for airplane landing gear. Many of the tire companies have tires under different names, for service similar to that of the Goodyear "Airwheel." These casings are designed primarily to operate at low air pressure and give the maximum in riding comfort.

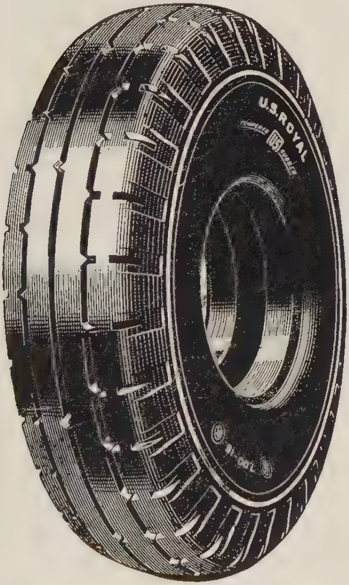


Fig. 8. U. S. Super-Balloon 16x7.00

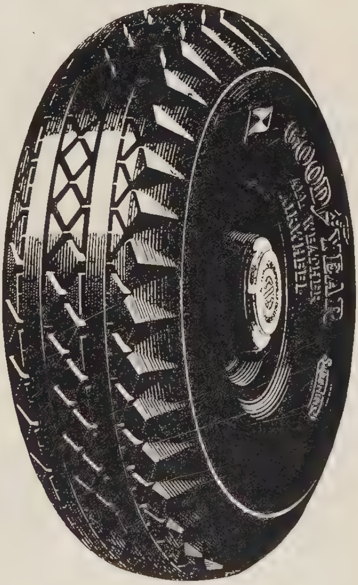


Fig. 9. Goodyear Airwheel for the Automobile

Fig. 10 illustrates a U. S. heavy-service bus and truck tire of 12-ply construction, designed to fit on a rim with 20-inch diameter, the carcass diameter or cross section of the tire being 9½ inches. The tires falling in this general classification, manufactured by the various companies, constitute a considerable portion of the production each year. The tonnage hauled in the United States each year on tires of this type is almost beyond comprehension. Day and night these tires are providing transportation for busses and trucks on all of our major highways, and the mileage secured from tires of this type runs to 50,000 and 100,000 and even more in many cases.

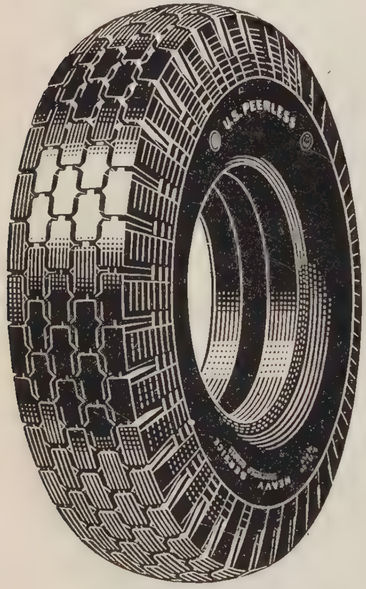


Fig. 10. U. S. Heavy-Service Bus and Truck 12-Ply 9.50x20 Tire

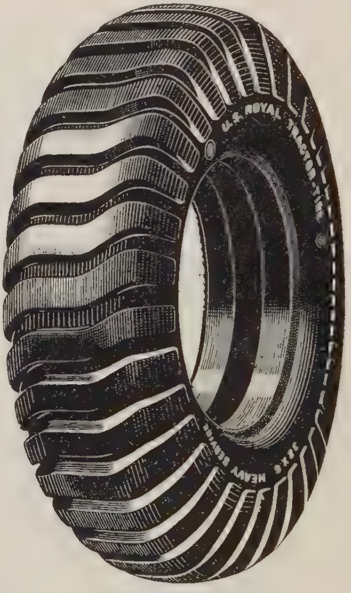


Fig. 11. U. S. Royal Heavy-Service Tractor Tire, 32x6

The U. S. "Royal" tractor tire, illustrated in Fig. 11, is typical of one of the newer uses to which pneumatic casings have been put. These are utilized not only for road work and general grading, but are also utilized by farmers for their tractors.

Aside from the uses mentioned above, which are some of the more common ones, we have the solid or semi-solid tire, sometimes known as the cushion tire, used for heavy duty hauling; the wheelbarrow tire which is a pneumatic tire; and the pneumatic industrial, which is finding usage in a great variety of jobs formerly cared for almost wholly by solid, cast-iron or wrought-iron wheels. The pneumatic industrial tire is novel, inasmuch as it is made somewhat on the order of the bicycle tire. No inner tube is used, the tire and tube being of integral construction. Naturally these tires are not designed for high-speed duty.

The introduction of the midget car, especially the midget racing car, which is largely a development by amateurs, has been further fostered by the development of a 12x4-inch midget racing tire. This tire is illustrated on the midget racer chassis, Fig. 12. These tires are designed to operate at a speed up to 100 miles per hour.

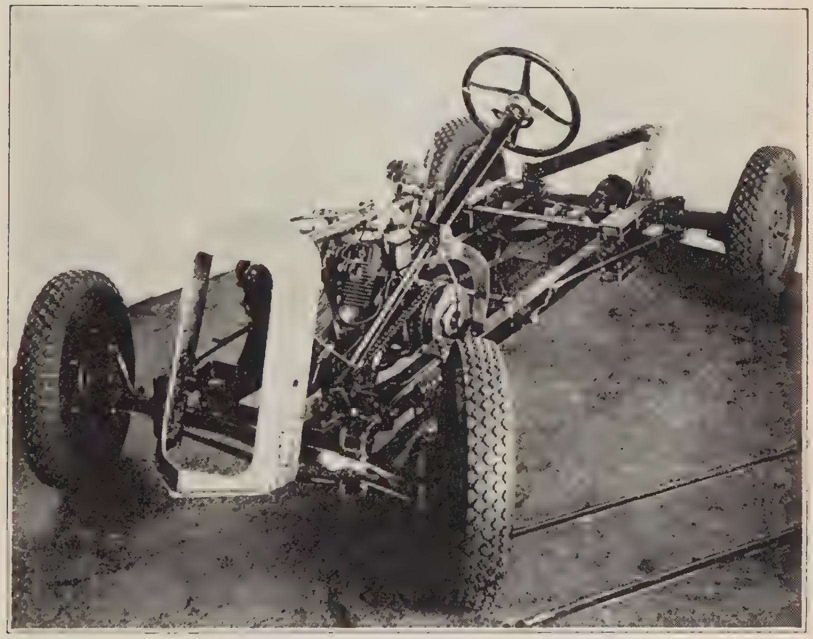


Fig. 12. Midget Car with 100-m.p.h. Race Tires, 12x4.00

Tire Loads. While it is not possible to give a great deal of engineering data in these pages, the chart, shown in Fig. 13, will serve to indicate the detail to which manufacturers go in working out tire data for the information of car manufacturers and service stations as well as for the users of tires. A number of items in this table will be of interest to the reader. The relative carrying capacity of tires of the same cross section, but different outside diameter, is

DIMENSION AND WEIGHT DATA—1934 DESIGN
Firestone "High Speed Balloon" (4 ply)
Firestone "High Speed Heavy Duty Balloon" (6 ply)

Size of Tire	No. of Plies	Size of Rim	Section Diam. Ins.	Outside Diam. Inches	Static Loaded Rad.—Ins.	Revs. per Mile	Weight in Pounds			Maximum Load in Pounds
							Tire	Tube	Total	
5.25–17	4	3.25-E	5.53	28.44	13.31	748	19.87	2.08	21.95	885
5.25–18	4	3.25-E	5.50	29.27	13.74	725	20.50	2.17	22.67	925
	6	3.25-E	5.62	29.74	13.97	715	25.42	2.17	27.59	1040
5.50–17	4	3.25-E	5.90	29.08	13.56	735	21.84	2.40	24.24	955
	6	3.25-E	5.85	29.23	13.63	733	26.82	2.40	29.22	1075
5.50–18	4	3.25-E	5.84	30.15	14.12	707	22.91	3.14	26.05	1000
	6	3.25-E	5.84	30.29	14.21	703	28.21	3.14	31.35	1125
6.00–17	4	3.62-F	6.12	30.02	14.00	713	24.34	2.94	27.28	1025
	6	3.62-F	6.12	30.07	14.03	711	28.96	2.94	31.90	1155
6.00–18	4	3.62-F	6.06	30.51	14.29	698	24.93	3.14	28.07	1070
	6	3.62-F	6.10	30.93	14.49	689	30.05	3.14	33.19	1205
6.50–17	4	3.62-F	6.64	30.86	14.33	696	27.38	4.09	31.47	1175
	6	3.62-F	6.62	31.12	14.50	688	35.28	4.09	39.37	1320
6.50–18	4	3.62-F	6.62	31.74	14.78	675	.....	......	.....	1225
	6	3.62-F	6.62	31.89	14.89	670	37.09	4.26	41.35	1375
7.00–17	4	4.00-F	7.05	31.55	14.62	681	32.44	4.09	36.53	1300
	6	4.00-F	7.02	31.67	14.72	677	39.83	4.09	43.92	1465
7.00–18	6	4.00-F	7.05	32.71	15.23	655	41.88	4.26	46.23	1525
7.50–17	6	4.19-F	7.60	33.19	15.39	648	49.46	5.36	54.82	1645
7.50–18	6	4.19-F	7.60	34.13	15.85	630	51.96	5.57	57.53	1710

Fig. 13. Engineering Data on Firestone Tires

given. The static loaded radius in inches has reference to the height of the center of the tire, or let us say the wheel spindle, from the roadway, with the tire under load, car standing. The total weight of the tire, including tube, is of interest. The revolutions per mile is of interest to all students of auto mechanics, inasmuch as it gives a basis for computation of car speeds, when the engine revolutions and gear ratio of the axle are known.

Tire Care. New generations of motorists are ever arising, and these need to be educated in the care of tires. Naturally a great deal of this education falls on the service man, inasmuch as he is in close touch with customers. Illustration *A*, Fig. 14, shows what happens to the tire casing when it runs flat. It will be noted that the rim sections are pressing the walls of the casing or tire together. Naturally if the roadway is rough and uneven, injury is almost certain to occur. Further than this, there is always a tendency of the casing to overlap itself, which means that cords are broken very quickly when the tire is run without air. For this reason, motorists must be educated to bring their cars to a stop as quickly as possible when a tire goes flat. On the other hand, considerable injury may be done to the flat tire if the car brakes are applied in a vigorous manner. The number of times tires blow out is relatively

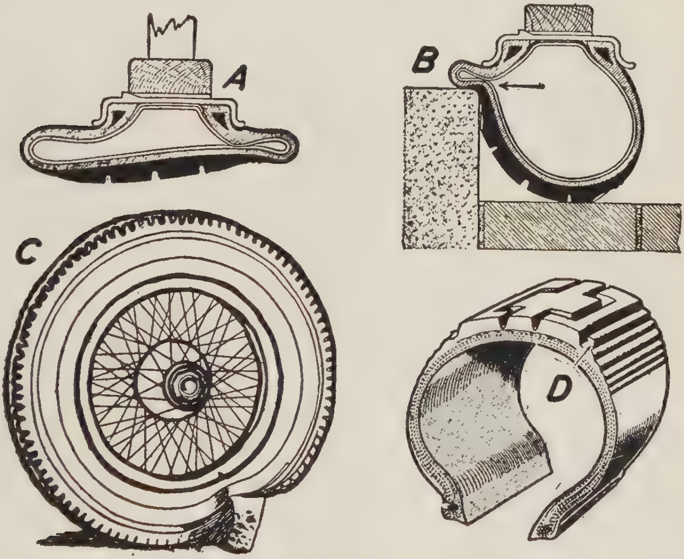


Fig. 14. A. The Deflated Balloon Tire Is Quickly Damaged
B. Balloon Tires Are Easily Pinched on the Curb
C. The Balloon Tire Is Subject to Stone Bruises
D. Section of a Balloon Tire

few, as compared with the old days when high pressures were used. As a matter of fact, breaks in the fabric usually result in a chafing of the tube, so that the air within the tube is allowed to leak out gradually; the tire will go down gradually, so that the motorist has a chance to know this by the swaying of the car or difficulty in steering.

Breaks within the tire fabric are caused by such misuse or abuse of the tire as that shown at *B*, where the side wall is being pinched between the curb and the section of the rim; or at *C*, where a tire is being driven over an obstruction, such as a rock, in the roadway.

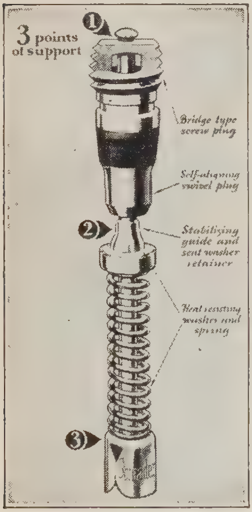

3 points of support
①
②
③
Bridge type screw plug
Self-aligning swivel plug
Stabilizing guide and seat washer retainer
Heat resisting washer and spring

Fig. 15. Schrader Valve Core

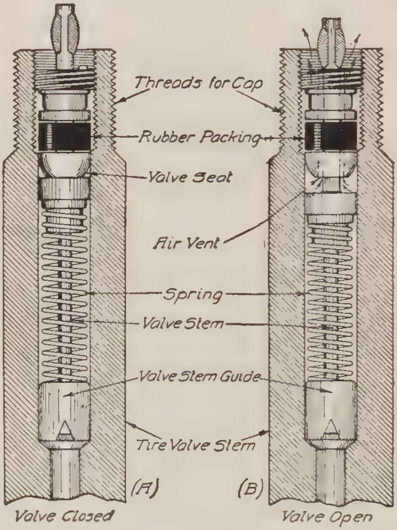


Fig. 16. Views of Tire Valve, Showing Closed and Open Positions

Note that the impact of the rock drives the fabric upward against the rim, with the result that it may be stretched beyond its elastic limit and broken.

If the service man will encourage his customers to come to his place of business regularly for checking the tire pressure, he will add greatly to the life of their tires. At the same time he will occasionally find repair work to do on the tires, which will insure a maximum of service for his customer.

Wheel Alignment. Rapid wear of tires on the front of the automobile, more often than not, is caused by misalignment of the wheels. By this we refer to toe-in, camber, and caster. Inasmuch as these items were treated fully in another section of these volumes, no further data will be given here. However, the repair man should familiarize himself with the methods of keeping tires from rapid wear owing to misalignment of front wheels.

Valves and Valve Cores. Fig. 15 illustrates a valve core before installing in a valve tube stem. The design of this core is quite similar to those illustrated in Fig. 16, where they are shown within the tube stem. Not a few tires are destroyed each season because of lack of care of the valve core. Valve-stem dust caps are allowed to remain off, with the result that dust or water enters the valve, destroying the core. Sometimes oil from the compressor finds its way into the valve stem and past the valve core, with the result that the rubber washer on the valve is destroyed. Leaking results, and this in turn permits the tire to be deflated, with the result that it is operated with low inflation pressure and rapid wear occurs. Valve stems or cores should be checked for leakage whenever the tires are inflated, and the dust caps should be locked on tight, in order to prevent loss of air from the tube.

Drop=Center Rim Tire Dismounting. Most passenger cars utilize drop-center rims, so that the service man is able to handle the mounting and remounting of these tires quickly. The dismounting will be done with the wheel on the car or with the wheel mounted on the changing rack; or he will do the work with the wheel on the floor or roadway. If the wheel is mounted in vertical position, first remove the rim nut and inflate the tube completely, either by removing the valve core or using a deflating cap. Next, loosen both beads from the ledges of the rim, using a tool to do this if necessary. After this, force the outside bead into the well opposite the valve hole. Next, place two tire tools about eight inches apart between the tire and rim, near the valve, and pry the bead over the rim flange. See Fig. 17. Follow around the flange with one tool until the outside bead is free. It is now optional whether the tube be removed before or after the second bead is removed. When removing the second bead, force the inside bead down into the well at the top of the rim, and grip the tire firmly at the bottom and pull straight out until the tire is free.

Mounting Drop=Center Rim with Wheel Vertical. First, turn the wheel so that the valve hole is at the top, and place the tire on the rim, guiding the valve stem through the hole. Push the inside bead only into the bottom of the well at the top of the rim. Next, force the remaining portion of the bead over the outside flange of the rim as far as possible, and if a tire tool is necessary, follow through with small bites. Apply the rim nut, turning on a few threads. Lift up on the tire by hand, and force the outside bead over the flange at the top side of the rim. Next, with one tire tool, start at either side of the valve and pry short lengths of the bead over the flange, continuing around the rim until the entire bead is in place. Often this can be done by hand, without the use of the tire tool. Always keep as much bead as possible in the well while applying the tire.

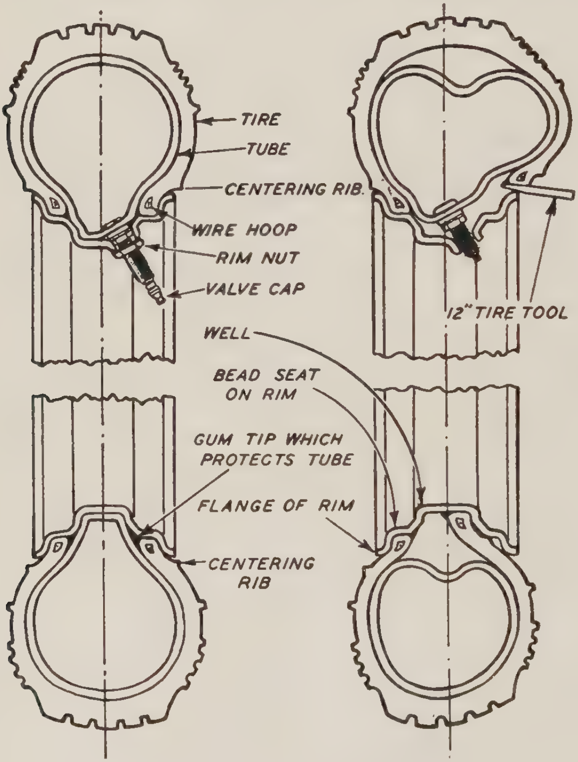


Fig. 17. Removing Tire from Drop-Center Rim

Before inflating the tube, remove the rim nut, push the valve stem back into the casing as far as possible, but not entirely through the valve hole, to make certain that the tube is not pinched under the bead. Pull the valve out again and apply the rim nut. Inflate slowly and see that both sides of the tire are centered on the rim, and that guide line on tire shows around the rim-flange evenly.

Dismounting Drop-Center Rim with Wheel off the Car. First, remove the rim nut and deflate the tube completely, either by removing the valve cap or using the deflating cap. Then loosen both beads of the tire from the ledges of the rim, using tools if necessary. Force the outside bead into the well opposite the valve hole. Place two tire irons, about four inches each side of the valve stem, between the tire and the rim, and hold the tire in the well with the knee, as shown in Fig. 18. Raise the bead over the rim flange by pushing down on the tire irons. Follow around the flange with one tool until the outside of the bead is completely free from the rim, then push the valve stem out of the wheel and remove the tube. Next, turn the assembly over and force the second bead down inside the bottom of the well, insert two tire irons under the second bead about twelve to eighteen inches apart, opposite to the portion of the tire that is in the well. Raise this part of the bead over the flange and stand on the tire with heels on the tire iron, being certain that the opposite side is down in the well. Lift the wheel free from the

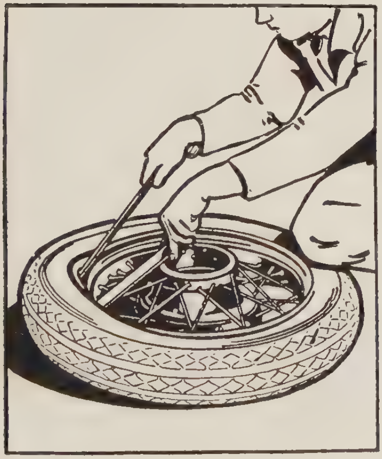


Fig. 18. Releasing the First Bead

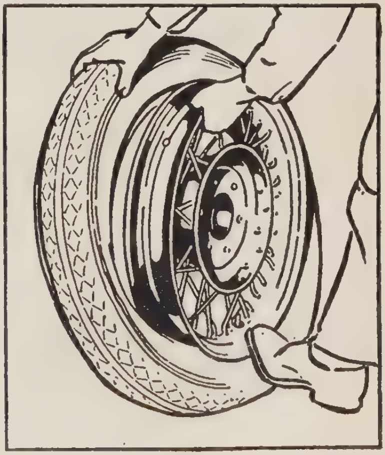


Fig. 19. Pulling the Wheel from the Tire

tire. In some cases it is easy to hold the wheel down on the tire with the foot and pull out the wheel at the top, as shown in Fig. 19.

Mounting Drop-Center Rim with Wheel off the Car. First, remove any foreign matter from the inside of the casing and inspect the rim to see that it is in good condition. Next dope the bead inside and outside with a good vegetable oil soft soap. The use of this soap will promote the ease of the mounting operation, inasmuch as the small beads which are designed to keep the inner tube from being pinched, will move readily over the rim, without sticking and having a tendency to turn under, thus locking or lodging the bead. Next, inflate the tube until it is barely rounded out, insert it in the tire, placing the valve at the balance mark. No flap should be used on drop-center rims. Next, see that the valve is straight and centrally located. Place the inside bead only, into the bottom of the rim well, at the valve hole. Push the valve stem through the valve hole in the rim nut a few threads, to prevent the valve from slipping back out of position. Test to see that the tube is not caught between the rim and the tire bead. Force the remainder of the bead, Fig. 20, over the rim flange.

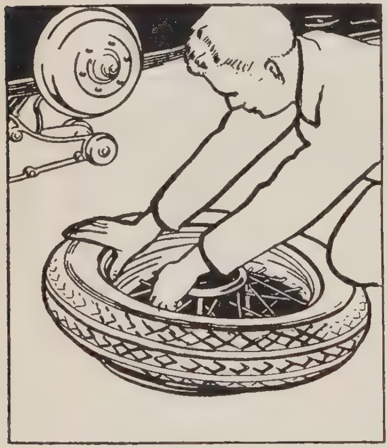


Fig. 20. Installing the First Bead

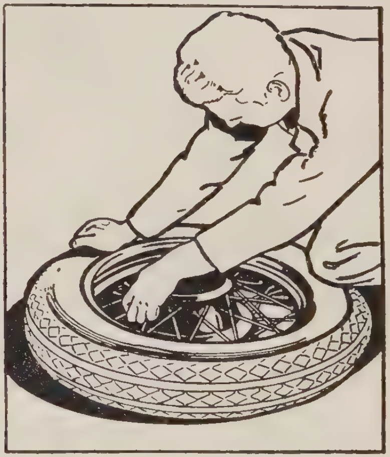


Fig. 21. Installing the Second Bead

When the valve hole is located inside of the well, place the second bead over the rim flange opposite the valve hole, Fig. 21. Place both beads down in the well. If the valve hole is in the center of the well, the bead can be started at the valve. Slip the remaining portion of the bead over the outside flange as far as possible, and if the tire tool is necessary, follow through with small bites until the entire bead is over the flange. Inflate the tube to about seven to ten pounds, and bounce the wheel assembly. Watch the centering rib, Fig. 17, so that it shows a uniform distance above the flange all the way round the tire, on both sides of the tire. If the tire has centered properly on the rim, inflate to the recommended pressure.

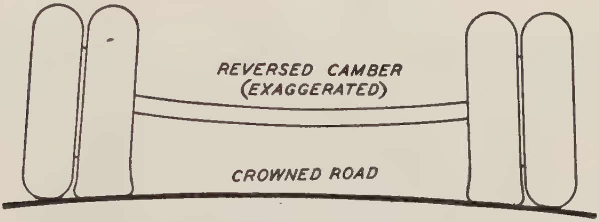


Fig. 22. Reversed Axle Camber Has the Effect of Increasing the Crown of the Road. The Different Rolling Radii, Caused by Reversed Camber and Crowned Road, Increase Tire Wear

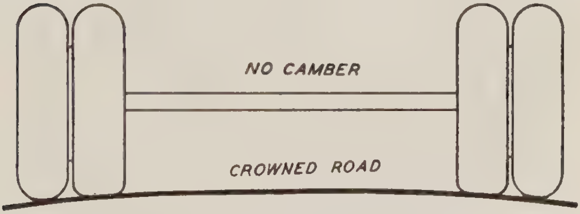


Fig. 23. The Crowned Road Causes Inside Tires to Carry More Than Their Share of the Load, Which Promotes Rapid Tire Wear

DUAL TIRES AND THEIR CARE

Heavy-service tires always have been known to fail more prematurely on the inside than outside dual wheels. These premature failures can be attributed to the increased strains which are imposed on the fabric and tread, and can be produced either by increased deflection and unequalized loads, which are due mainly to reversed axle camber, Fig. 22, or by road crown, Fig. 23. Dual tires, Fig. 24, must rotate together, even though they usually have at least slightly different deflections and rolling radii and are therefore subject to greater action than tires operated on single wheels under the same conditions of load and inflation pressure. The present era of excessive overloading has tended to aggravate this situation.

The main factors involved in the service problems which arose with the use of the dual tire, may be summarized: effect of reversed camber, due to excessive loads causing sprung axles; effect of crowned roads on tread and carcass wear; differential inflation pressures in dual units (inside and outside) to partly compensate for the above; proper mating of duals.

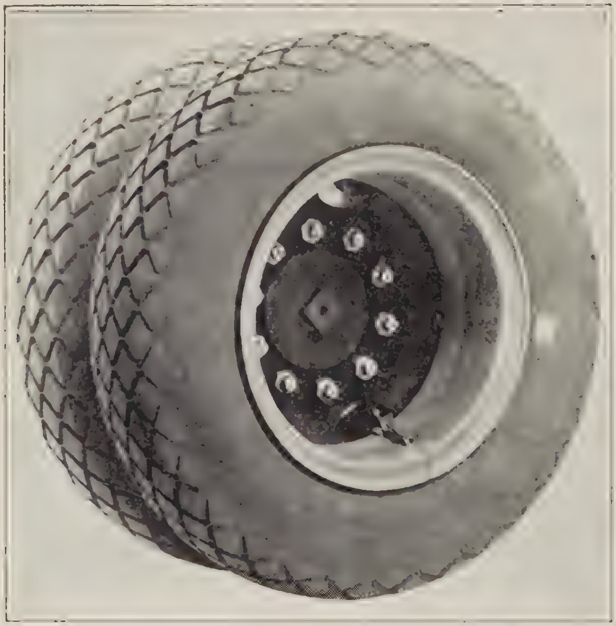


Fig. 24. Dual Tires on Dual Wheels and Rims

Effect of Reversed Axle Camber. Since the load is suspended on the axle at two points, one at each end of the axle but within the inside tire, it causes reversed camber, or downward deflection at the middle of the axle, and consequently a greater deflection of the tires on the inside wheels than of the tires on the outside dual wheels. The result is that the inside tires support a correspondingly greater load than the outside tires. This condition, Fig. 22, is greatly aggravated by excessive loads or sprung axles.

Effect of Road Crown. The average profile for paved roads constructed at present is a parabola, whose curvature depends on the width of the pavement. Some older paved roads were built with circular profiles and higher crowns than at present. Gravel and macadam roads have a much greater crown. Data collected shows that overloads as high as ten per cent can be attributed to the crown, Fig. 23, of ordinary paved roads, while on gravel and macadam, much greater overloads may be expected.

Differential Inflations to Obtain Equalized Loads. A common procedure used to minimize the bad effects of reversed camber and road crown, is to reduce the inflation pressure of the inside tire by about 5 pounds. In the cases where the inflation pressure is adjusted to give equal loads on inside and outside dual tires, it is necessary in some cases to have a difference of as much as 22 pounds to equalize the load. Since over-inflation is not as liable to produce premature tire failures as under-inflation, the inflation pressure of the outside tires should be increased, rather than reduce the pressure of the inside tires in order to equalize the load between the two tires.

No set rule can be made for the amount of pressure increase in the outside tires, as this will vary with the operating conditions of each vehicle. Tires on heavily overloaded trucks running on narrow, high crowned roads, would require the greatest pressure differential. This would be graduated downward to no differential pressure for trucks without reversed camber to be run on perfectly flat roads—an ideal condition seldom found in practice.

Care should be taken not to increase the pressure in outside tires to a point where they are over-inflated more than 15 per cent over the recommended pressures. Usually a 5 to 15 pounds greater pressure in the outside tire will greatly improve the load distribution and service of the tires. In some cases, a higher differential may be necessary. In any case, where the operating conditions indicate the need for unequal pressures, any differential pressure that is used, will improve the service of the tires. It is a question of trying different pressure combinations until one is found that gives the best results. It should also be noted that as the tires wear, the required differential pressure changes.

Proper Mating of Duals. Worn tires should always be placed on the inside of the duals and new tires on the outside position.

Reversing this practice will not only overload the inside tires and produce premature carcass failures, but rapid and irregular tread wear as well. A badly worn and new tire should never be run together on the same dual, regardless of position. To do so may bring the entire wheel load on the one new tire.

Removing Tires from Truck Rims. Most truck rims are provided with a flat base rim having removable side rings and the locking rings. First, remove the valve cap, deflate the tube with a deflating cap, and remove the valve core. Next, loosen the locking ring by pounding the side ring downward with a heavy mallet or lead hammer, after which pry out the end of the locking ring, and while standing over the tire, continue to roll on the rim until the lock ring is completely out. Lift off the lock and side ring, work the tire and flap loose from the rim. The thin end of a broken spring leaf makes a good tire tool, supplying sufficient leverage to force between the rim and bead and the flap. This can then be driven around with a hammer. Next, push the valve through the valve hole into the casing. Next, turn the tire over and, with the rim iron, pry the bead away from the inside flange, working around the tire and finally lifting the rim out of the tire.

Mounting Tires on Truck Rims. When remounting, first inflate the tube to just round position. Remove any foreign matter in the tire and dust the inside well with talc. Insert the tube and flap, centering the flap and seeing that the valve is straight. If the rim is rusty, it should be scraped and thoroughly cleaned. A graphite preparation, if available, is helpful as a lubricant for the rim surface. Bent or warped side and locking rings should be straightened before reassembling. Place the tire on the rim, placing the valve through the slot in the rim. If single angle or double angle valve is used, the end of the valve should point upward. Lift down portion of tire upward and allow the whole tire to drop over the rim.

Place blocks under the rim, three of these being sufficient, and raise the rim from the floor to allow the tire to rest on the bottom flange. Drop side ring in place, insert one end of locking ring in rim gutter about one-quarter way around from the valve. Some rims have a notch in the gutter angle, into which a small stud in the end of the lock ring fits and these must be fitted together regardless of distance from the valve. Continue to pry the lock ring in place around the rim. Use care not to overspring the rings and spring them out of shape. Inflate the tube slowly to the recommended pressure, keeping the movable rings away from operator for the sake of safety.

HINTS FOR MOUNTING AND DISMOUNTING TIRES

Correct procedure and good mechanical judgment in tire dismounting and mounting, mean ease of operation. Tire changing efficiency is reached by following recommended practices.

Dismounting. With tires having no balance mark, chalk the casing at the valve. This will enable you to replace the casing in the original balance position. Proceed on the principle of taking the rim out of the tire, rather than taking the tire off the rim. The use of light, penetrating oil will assist removal of rusted locking rings and make reassembling easier. However, remove excess oil so that it does not come in contact with tire, tube or flap. Always use deflating cap on valve, or remove valve core, to be certain that tube is completely deflated.

Partially jack car up, leaving some wheel pressure on the ground, which will hold the wheel steady while exerting extra force necessary to start the hub or stud bolts. When loosened, jack the tire up to full dismounting height, and proceed to remove the tire and rim.

Points to Check between the Operations of Dismounting and Mounting. Check wire wheels for loose or protruding spokes. Call car owner's attention if any are observed. Straighten all bent rim flanges. Put in good shape before mounting tire. Inspect clincher rims and see that the rim clinches are true to shape; otherwise they will damage the beads on the casings. Check monogrammed hubcap plates. See that they are tight and will not rattle. Clean all foreign matter from the rim with a wire brush. A coating of rim paint is a worth-while service.

Removing foreign matter from rim gutters will assist in the assembling of side and locking rings. Lubricate all rim nuts, studs, and locking mechanisms. This will assist in assembling.

Check rim strip on drop-center wheels and rims. Rim strips are used to protect the inner tube from being chafed or punctured by the spoke ends or nipple beads. If not smooth and in good shape, replace and fasten permanently to the bottom of the well with rim cement or shellac. Do not mount a wet tube in a casing. See that it is thoroughly dry before assembling.

Inspect the inside of the casing thoroughly before inserting the tube. Even a small piece of wrapping paper will injure the tube or casing. Dust the inside of the casing lightly with talc. A slight dusting of talc on the tube is recommended. Remove all excess talc from the casing.

Mounting. The hex nut on the tube should be tightened with a wrench. Inflate the tube just "into the round" and apply in casing. If flap is used, see that it is centrally located. Keep the tube and flap well up into casing when mounting on rim. See that the valve stem is straight and in correct position to fit the valve hole in the rim.

A valve should not be located so that it will be forced or strained into position after the tire is assembled on the rim. This might cause the valve to chafe and even break through, in service.

Do not attempt to mount both beads of a drop-center tire at one time, as the "well" portion of the rim is not wide enough for two beads. Forcing both beads into the "well" strains the beads, makes the assembly more difficult, and is injurious to the casing. Place the valve at the balance mark on the casing. Place puncture-sealing tubes in the casing with the valve 180 degrees from (opposite) the balance mark.

Tighten the rim lugs or wheel studs lightly at first, checking to see that the tire and rim or wheel are true circumferentially and laterally. A wobbly wheel means lost miles. Continue to tighten alternately until all are tight.

Excessive force in any dismounting or mounting operation is unnecessary and indicates incorrect procedure.

Protecting Equipment. Tires, rims, and wheels are an important part of car appearance. Service men should exercise every caution to protect the customer's property.

When mounting tires on wheels removed from the car, place a protective cloth, such as canvas, on the floor to prevent wheel disfiguration. Disc wheels are subject to extra caution.

A rubber mallet is as efficient as a metal hammer and prevents damage to painted or polished surfaces. A piece of inner tube between the tire iron and wheel or ring surface, will preserve same against scratching.

A few drops of penetrating oil will loosen dirt- or rust-bound locking rings, making extreme force unnecessary and thereby preventing ring distortion or damage.

After mounting white or colored sidewall tires, clean with U. S. Royal White Sidewall Tire Cleaner.

Cover portion of tire tools not in contact with tire or rim, with rubber or tire tape to prevent nicking and scratching the surfaces. Use correct wrenches. A slip may mean a disfigured wheel.

Good Tire Service Suggestions. An old, dilapidated and shrunken flap does not provide suitable tube protection, and may easily cause early tube failure and casing damage. Sell a new flap whenever necessary.

Never change a tube valve by forcing it out through the valve base. This valve base has a fabric reinforcement and is damaged by valve removal. Cut the tube a foot or so away from the valve, remove the valve from the inside, insert a new one through the hole; then repair the opening with a tube patch.

Lubricating tire beads with a light treatment of vegetable oil soft soap will greatly assist tire mounting. This is particularly important for all clincher and drop-center tires.

Avoid damaging the feather-edged rubber toes of all clincher and drop-center-rim casings; these fin-like edges prevent the tube from chafing and bead cutting.

When dismounting casings which are frozen to the rim, ease the beads from the side flanges, remove all demountable rim parts and work the tire and flap away from its frozen seat. An 18-inch section of an old spring leaf ground down to a long tapering thinness, driven between the tire or flap and the rim seat, will greatly facilitate dismounting.

Casings which positively cannot be removed from the rim by any other means, may be run flat for a few hundred feet. This is, however, the last resort and should only be done on completely destroyed casings.

Another method which may be used to remove casings which have frozen to the rim is to remove the valve core and side flanges and inflate the tire a few pounds. Great caution should be exercised when following this method or the tube will be destroyed.

Have respect for compressed air. Even 5 pounds of air in a

6.00x18 tire, means a total force of many hundred pounds. Locking mechanisms are designed to be safe, but nevertheless the operator should keep the locking-ring side of a recently mounted tire away from him for the sake of safety.

When inflating tires on cars, keep to one side—there is little opportunity to dodge a flying rim flange or locking ring. Caution is always a rule of safety.

Rotating of tires from front to back wheels is to be recommended and is mileage economy—from right front to left rear, etc.

Spare tires should have tire covers. Spare tires should not be left for long periods on spare tire carriers. They should be placed in running position every 1,000 miles or so.

The best tires should be mounted on the front wheels.

It is the air in the tire that carries the load. Keep the tires inflated to recommended pressures.

Use all tire tools as they are designed to be used. Screw drivers are not meant to be used as tire tools or drift-pin punches.

Keep tools in good condition, in their proper place. Good tools, correctly used, are half the job.

INNER TUBE REPAIRS

Punctures and Blowouts. Open up hole or injury by trimming edges. Thoroughly buff edges, stretching tube, if necessary, to aid in buffing. Wet a clean piece of flannel cloth with a high-test solvent, such as benzol, insert through the hole and wash inside of the tube for an inch or more around the injury. Cement the inside surface and walls of injury with tube-repair cement. Cut a piece of cured back tube-repair gum large enough to extend beyond injury about half an inch all around. Using long-nosed pliers, dip the patch in solvent and insert through the injury, with its raw gum face next to the underside of the injury. When the solvent has evaporated, press the patch into place.

Now fill the injury with tube-repair gum. Roll down and trim the edges flush with surface of tube, leaving the center slightly higher to insure proper pressure in curing. Too much gum, or excess pressure during the cure, will cause the repair to bulge.

In the case of pin holes or small punctures, the inside reinforcement is not necessary.

To get a smooth surface on the repair, have a piece of holland between the tube and the hot plate during the cure.

Valve-Hole Repairs. The quick way to repair a valve hole that has been damaged, is to have on hand a supply of ready-made valve patches. Two kinds are manufactured by the rubber companies, one a flat patch, the other a curved patch cured to fit the shape of the tube.

First, push the valve stem inside the tube. Trim out the ragged edges and buff the surface around the injury, slightly larger than the valve patch to be used. Also buff the concave or underside of the valve patch. Wash the buffed surfaces with solvent, and coat with tube-repair cement. When the cement is dry, fill the hole with tube-repair gum and apply the valve patch over the hole, rolling down firmly.

Cure on tube plate, using a section of an old tube for a cushion or pad under the block, to help give proper pressure around the edge of the patch. When cured, cut a small hole in the center of the patch (smaller than the diameter of the valve stem) and push the valve stem through from the inside of the tube.

Substituting Fabric for a Valve Patch. In case you do not have any factory-made valve patches on hand, you can use two pieces of square-woven tire-repair fabric instead, one as an inside reinforcement, the other over the outside, the same as the regular valve patch is used. Of course, a properly cleaned and cemented foundation must be prepared for the inside reinforcement as well as for the outside patch.

Vulcanization. Vulcanization so changes the physical properties of rubber as to render it less plastic and more resistant to wear and mechanical strains. Vulcanized rubber is a product resulting from the chemical union of crude rubber and sulphur, and as heat accelerates all chemical reactions, the aid of steam is employed to bring about a quick union of crude rubber and sulphur.

It is generally known that other chemicals than sulphur are also used in compounding. These chemicals do not unite with the rubber but are highly dispersed through the mass, and their presence gives to the rubber certain desirable properties, such as resistance to wear and abrasion, resiliency, and strength.

Sulphur and rubber combine very slowly under atmospheric conditions, and this is what is called spontaneous cure. It takes months for this curing to materially affect the physical properties of the product, so this method is of little importance to the average vulcanizer.

Now, according to certain laws of chemistry, an excess of any element entering into a chemical combination, greatly accelerates the speed of reaction. It is for this reason that it is necessary to use an excess amount of sulphur. However, this excess, unless it is too great, does not in any way affect the physical properties of the vulcanized rubber. Rubber blooming is nothing but the excess of sulphur in the vulcanized rubber working to the surface.

It is also true that some of this excess sulphur never blooms, and as rubber ages, there is a slow process of spontaneous vulcanization going on which is called "after cure." It is for this reason that rubber, when very old, sometimes becomes hard and lifeless and has a tendency to chip easily.

Well-made repair materials are compounded with the correct amount of ingredients, so that when properly cured the effect of "after cure" is reduced to a minimum. For the above reasons, to get good results it is absolutely necessary to use the temperature and time recommended by the manufacturers of repair materials for curing the different repairs. This information is found in their tire repair manuals, available to users of their products.

Small Tool Equipment. The well-equipped tire repair shop should have a considerable quantity of small tools, among the necessities being those shown in Fig. 25. At *A* is shown a flat hand roller and at *B* a concave roller. *C* shows an awl, or probe, which is used for opening air bubbles and sand blisters. *D* is a smooth stitcher; *F* a rubber knife, of which two sizes are advisable, a large and a small; and *G* a 10-inch pair of shears for trimming inner tube holes, cutting sheet rubber, etc. *H* is a steel wire brush for roughing casings by hand; a preferable form is a rotary steel wire type driven by power at high speed. *I* is a similar wire brush for roughing tubes; and *J* another brush with longer wires, also for roughing casings; *K* is a tread gage for marking casings to be retreaded; and *L* a fabric knife necessary in stepping down plies of fabric. *M* is a pair of plug pliers for placing patches inside of small tube repairs; *N* is a cement brush for heavy casing cement, another very much smaller and lighter one—preferably of the camel's hair type—being used for tube cement. *O* is a hand scraper and *P* a tread chisel; *Q* performs a somewhat similar function, being a casing scraper for cleaning the inside of a casing preparatory to mending a blowout.

In addition to the small tools shown in Fig. 25, it is necessary to have several tube-splicing mandrels; a large number of various sizes and shapes of clamps for all purposes; rules, try-squares, and other measuring tools; tweezers for handling small patches, tools for recutting threads on tire valves; tire spreaders, for holding casings open when working inside; a casing mandrel or tire last of cast iron for holding a casing when making repairs; a tread roller for rolling down layers of raw stock evenly and quickly; a considerable amount of binding tape; thermometers; and such motor-driven brushes, scrapers, etc., as the quantity and quality of the work warrant.

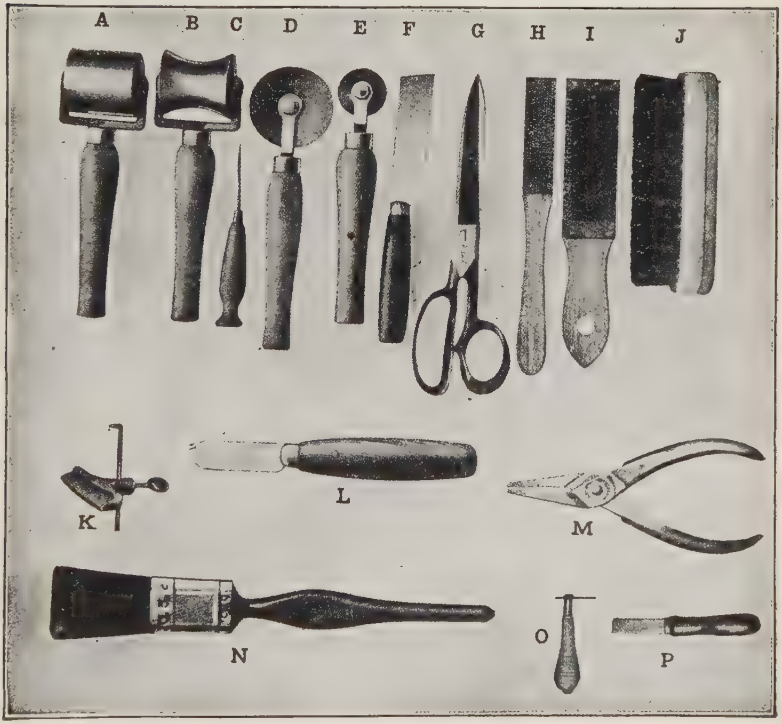


Fig. 25. Collection of Tools Necessary for Vulcanizing Work

INSPECTING, REPAIRING, AND VULCANIZING BALLOON TIRES

GENERAL INFORMATION

When the customer brings the tire to you, first make a careful inspection of it for ply separation, tread separation, nail holes, or other injuries, estimating the possible remaining mileage in the casing. If you will make use of a tire spreader or tire inspection machine, you can show the customer the exact condition of the tire.

Tires which are old and show cracks in the rubber and lack resiliency or life should not be repaired. Small cracks on the sidewalls do not mean that the tire is beyond repair. However, should the tread be cracked and lack life, it is not recommended that an attempt be made to repair it. If the sidewalls have turned white and the treads are a brownish color, it usually indicates age.

Make a careful inspection to see whether there is any separation between the tread and the carcass before repairing the tire. Where this condition exists, moisture is usually between them. When a cure is made, the tire may blow; it is almost certain to bulge and raise up.

Tread separation will show if a spreading machine is used. If no spreading machine is available, use the hands, pressing the tire with the thumbs all the way round.

If you have made your inspection in front of the customer and for his information, you will be in a position to advise him of the approximate cost of the job as well as the amount of mileage he may reasonably expect from the repaired tire.

Preparing the Injury. Prepare the injury by trimming away all the injured fabric and rubber. The walls of the cavity or injury must be cut on an angle of 45 degrees from the outside toward the center of the injury. It is better to remove too much material around an injury than to have some of the injured material remain. If the injury in the tire is broken all the way through, first cut out the injury from the inside of the casing on the straight, $\frac{1}{8}$ inch into the solid; and then from the outside, skive to the first ply on the inside on a 45-degree angle. If the injury is only broken through the surface and not the tread, skive from the inside on a 45-degree angle. Wet or water soaked tires must be dried thoroughly before attempting to repair them.

Buffing. In order to have the cement adhere and vulcanize to parts of the old tire, it is absolutely essential that a good job of buffing or roughing up be done. This buffing not only roughens the material but exposes clean stock to which the cement will adhere. There are a number of buffing tools on the market, the most commonly used being the flexible shaft which carries a 4-inch buffing wheel or wire brush. These machines are adapted to make use of certain tools built up in the nature of files or rasps. When buffing the inside of a casing, make very certain that all traces of the lining cement, which is put into the casing at the time of manufacture to prevent tubes from sticking, is removed.

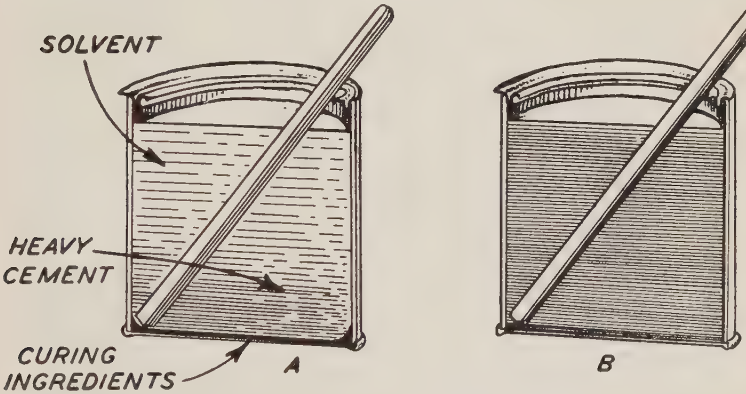


Fig. 26. Showing Cement in Can. A. Before Stirring; B. After Stirring

Cementing. If the student repair man really understands that the application of cement, gums, and fabrics, and their proper vulcanization into the tire so as to form a permanent repair is in reality a chemical process, he will have a better appreciation of care and cleanliness. It took many years of experimentation to finally discover a process by which rubber could be vulcanized. In fact, the discovery was a matter of accident as well as planned effort.

Foreign materials have no place in cement. Keep the cement cans closed when not in use and remove only enough to care for the immediate job. See that the cement is thoroughly mixed before pouring out of the can. Since the cement is principally rubber and a solvent and the rubber is heavier than the solvent, it will gradually settle to the bottom. It will be seen that unless this rubber is stirred frequently, the solvent only will be used and the cement will gradually thicken. If thin cement is used, there will not be enough body to hold. If thick cement is used, it will not work well. Experience will show just the proper body for the cement. See Fig. 26.

On the ordinary job, two coats of cement should be applied and, with Goodyear vulcanizing cement, twenty to thirty minutes will be sufficient time for the first coat to dry, the following coat requiring 30 to 45 minutes. Do not allow the cement to dry too long before building up the tire. The practice of allowing the cement to dry overnight is no longer necessary nor recommended. Nor is it recommended that a cemented tire be dried in the sunlight. A drying room is highly desirable. Naturally, cement dries more rapidly on clear days than on damp or dark days. These conditions must be taken into account, the length of time between coats being longer on damp or dark days. A good tackiness of the cement should be secured in every case before building up. In case you are unable to follow through on the tire when the cement is just right, it is a good plan to apply a thin coat of cement a short time before starting work on the tire.

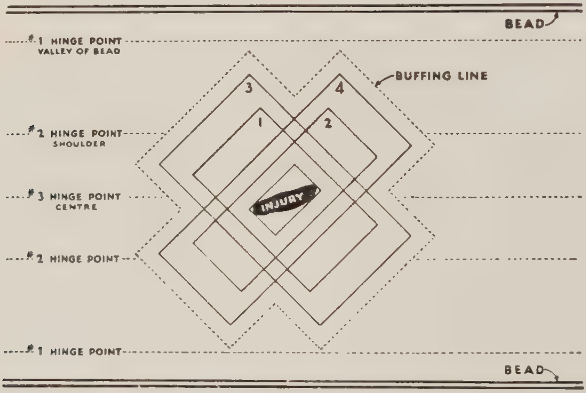


Fig. 27. Drawing Showing Inside Sectional Repair with Same Points Indicated as Shown in Fig. 2

Drying Room. Foreign materials in cement or on rubber will cause some degree of failure. If a dustproof drying room can be made available, it should be used. The room should not be hot and should have an even temperature. Provide this room with hooks or brackets and racks which will permit a circulation of air around all parts of a cemented or repaired tire so as to allow all parts to dry evenly. No part of the repair should be in contact with a rack.

Goodyear Criss-Cross Method of Balloon Tire Repair

Nature of Injury. The criss-cross method of repair is designed for injuries which occur between No. 1 hinge points of the casing. This feature of construction may be understood by making a study of the cross-section of the tire illustrated in Figs. 2 and 27. Small injuries and nail holes are not repaired by this method.

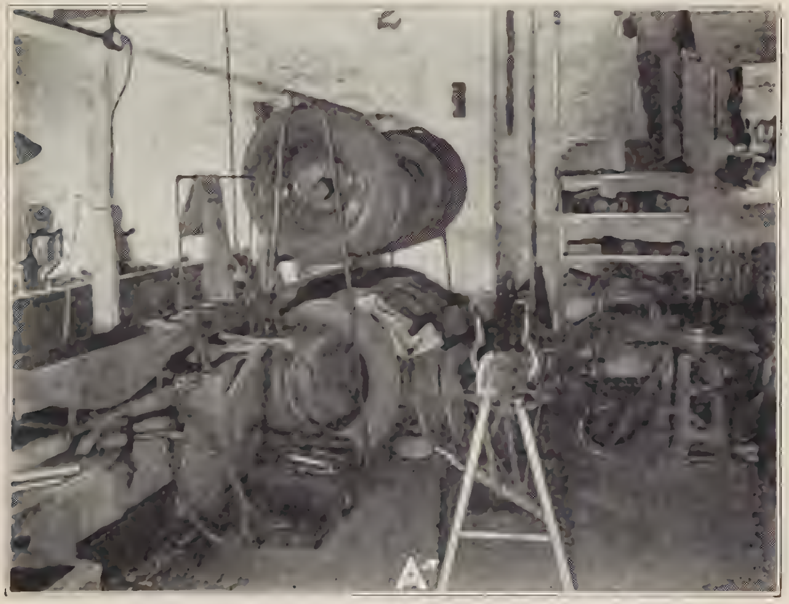


Fig. 28. Corner of a Tire Repair Shop Showing Tire Spreader, Tube Test Tank, Buffer, Rim Spreader, Tire Rack, and Other Equipment

Preparing an Injury. Trim back the injured fabric and tread to the solid material. Skive or cut down the injury from the outside to the first ply on the inside at an angle of 45 degrees. Do this work carefully, making a thorough inspection to see that solid material is encountered all around the hole opened up by skiving.

Buffing. Spread the tire open on a tire spreader *A*, Fig. 28. If no tire spreader is available, a tire mandrel may be used; but this method is not so good as the use of the spreader. Proceed to buff the area around the injury that is to be covered with fabric and cushion stock. Any points within the tire that are buffed and not cemented and cushioned will weaken the tire as the buffing robs the cords of their insulation and they will chafe and weaken. In order to determine exactly how much area is to be buffed, lay out a square or rectangle *A*, Fig. 29, around the injury, being very careful to include the entire injury and have two sides of the square or rectangle running parallel with the cords of the inside ply of the tire. Next measure outward 1½ inches on the four sides of the area marked out and lay out another and similar figure, only larger. See *B*, Fig. 29.

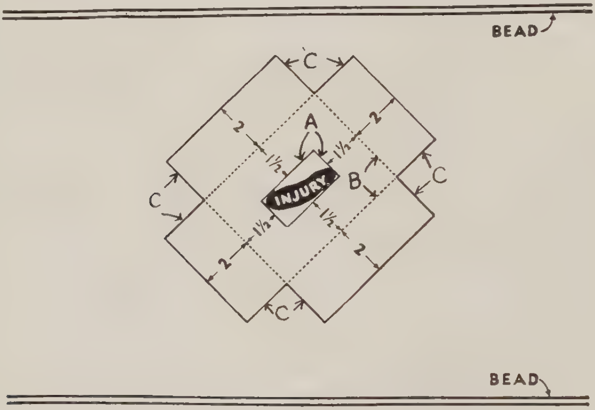


Fig. 29. Method of Laying Out Area for Buffing

The next step is to extend the sides and ends of this larger rectangle or square 2 inches, so that you will have the cross illustrated by lines *C* in Fig. 29. Now proceed to buff the area included within the outlines of this cross.

Cementing. After buffing, clean the tire injury most carefully, removing all evidence of the buffing. This work may be done by means of compressed air or with a bristle brush. Next wash the buffed surface with a coat of cement solvent. This work should be done in the dry room, if one is available. At any rate it should be kept in a clean location. The solvent will dry very quickly.

Before applying the first coat of cement, spread the tire open and insert wooden spreaders to hold it open a little wider than its normal position. Have the cement thoroughly mixed and of proper consistency. Brush in the first coat of cement quite thoroughly. Make certain that the edges of the injury are cemented. A small brush is recommended for this work. Allow twenty to thirty minutes to dry the first coat, then apply the second coat in the same manner as the first. After this coat has been applied, the spreaders should be removed and about forty-five minutes allowed for the second coat of cement to dry. Since the tackiness of the cement is the real indication of when the drying has proceeded to a proper point, the time element alone may not be depended on but a check-up made to see how the drying is proceeding.

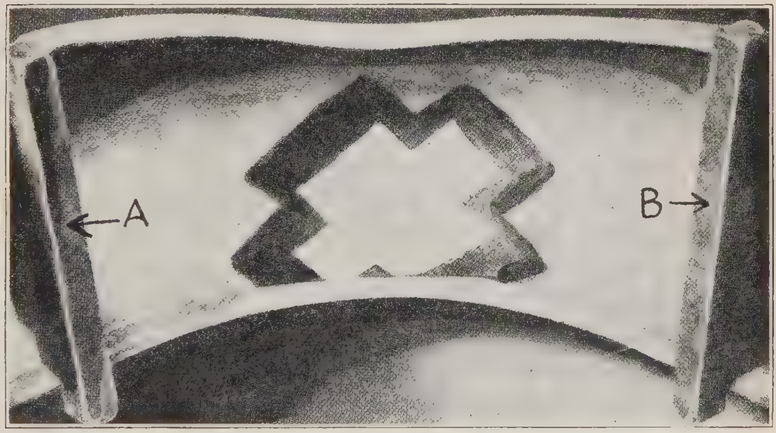


Fig. 30. Section of a Tire Built Up with First Two Plies of the Criss-Cross Repair. *A* and *B* Illustrate Wood Spreaders in Position

To do this, feel the cemented surface with the back of the hand. If the cement has reached the proper stage of tackiness, it will pull the hair on the back of the hand to a noticeable degree. When the cement has reached this point of tackiness, build up the repair at once. It is not advisable to allow the cemented tire to stand overnight before building up. This is true if Goodyear or other fast-drying cement is used.

Building=Up the Repair. With the tire on the repair table, place a small piece of holland on the table where the tire is to rest so that the cemented injury that rests on the table will not come in contact with any dirt or foreign matter. Place the tire in a vertical position, leaning it against some support or bracket or hold it in position by a chain suspended from the ceiling. Insert the wood spreaders *A* and *B*, Fig. 30, holding the tire open enough so that the new material can be easily applied. Do not spread more than necessary as it is desired to hold to the original shape of the tire as much as possible.

Cement a disc of $\frac{1}{32}$ gauge cushion gum, 1 inch larger in all directions than the size of the injury. Stitch this in position centrally over the injury. Next take the necessary measurements so that all material can be cut at one time. The length of the first ply varies, depending upon the number of plies in the tire, according to the following table:

No. of plies in tire	Length of first ply in repair
4-ply	4 inches longer than injury
6-ply	5 inches longer than injury
8-ply	6 inches longer than injury
10-ply	7 inches longer than injury
12-ply	8 inches longer than injury
14-ply	9 inches longer than injury

If the tire under repair is of four-ply construction, the first ply of new fabric should be built in with the cords running in the same direction as the cords on the inside ply of the tire. The second ply is placed in the tire so that the cords run in the opposite direction or at right angles with the cords of the first ply. Successive plies alternate in the same manner. Determine the measurement of the material by measuring the widest part of the bevel in the injury. The length of the first ply will be the measurement across the injury in the same direction as the threads of the inside ply of the tire plus 4 inches. The width of the first ply will be the measurement of the injury across the direction of the threads of the inside ply plus 1 inch. The second ply will be measured for length at right angles to the first and will be the extreme dimension of the injury plus 4 inches. The width will be the extreme dimension of the injury to be covered plus 1 inch. The third ply will be measured in the same manner as the first and will be 2 inches longer and 1 inch wider. The fourth ply will be measured in the same manner as the second and will be 2 inches longer and 1 inch wider. Reference to Fig. 27 will make these directions clear.

Sufficient cushion gum should be cut in half-inch strips to bind in the edges of each and every ply of new material. Be extremely careful that all repair material is clean and tacky before installing.

Plies of cord fabric are cut on the straight and not on the bias. New material should be built into the tire under a slight amount of tension in order to avoid bulging when the spreaders are removed and the tire takes its natural shape.

Center the first ply over the injury with the cords running in the same direction as the cords in the inside ply of the tire, allowing it to slightly bridge the injury. Next stitch the ends ½ inch. Now stitch from the center both ways. Apply all plies uniformly. After the first ply is stitched thoroughly, bind the edges with cushion gum ½ inch wide, lapping the new material the width of one cord, then stitch thoroughly.

Center the second ply the same as the first, except of course, that the cords will be running at right angles to the first ply. Bind the same with cushion in the same manner as the first ply.

The third ply is to be run parallel with the first, overlapping lengthwise by 1 inch at each end and ½ inch at each side. Bind the edges of this and stitch as in the first two plies.

The fourth ply is to overlap the second ply at each end by 1 inch and ½ inch at each side. The edges should be bound and the ply stitched carefully.

Cover the remaining buffed and cemented surface inside the tire with cushion gum to within ⅛ inch of the outer edge. As the cushion stock flows in curing, it will run to the edge and make a perfectly smooth repair. Before turning the tire over to finish the repair on the outside, make a careful check to see that there are no blisters or trapped air.

In order to build up the outside of the injury, place the tire on a snug fitting mandrel so as to keep it in its natural shape. Fill the injury with cushion gum to the level of the fabric, being certain that no air is trapped. Stitch thoroughly and then fill up with tread stock level with the tread.

If all work indicated has been done carefully, the job is now ready to be cured. It should be remembered that the more neatly and carefully a tire is built up the greater chances for complete success of the repair after the cure has been made.

Repairing Small Injuries and Fabric Breaks. Small injuries through the tire which are less than 1 inch long may be repaired by hanging the tire over a wood block and cutting straight through the tire around the injury with a 1-inch diameter punch and mallet. Use a rat-tail rasp for buffing the fabric walls of the carcass cut out by the punch and a cone-shaped rasp on the tread portion to bevel the injury through the tread portion to approximately 45 degrees. The inside surface buffing, cementing, and building in of new material is the same as recommended for standard criss-cross repair work, the size of the fabric used being based on a 1-inch round injury. Just as much care must be used to see that buffing, cementing, stitching, and other repair operations are thorough as in the larger repairs.

In case of small fabric breaks which do not extend through the tires to the outside, they may be repaired by skiving down the injury from the inside to an angle of 45 degrees until a solid surface is encountered. After this, the space for buffing is laid out the same as in the criss-cross method and the repair proceeds in the same manner.

Nail Holes. When a tire has been punctured by means of a nail, bolt, screw, or other similar object, it is a good plan to plug the hole so as to prevent chafing of the fabric and subsequent development of trouble. One method of making such a repair is to use the Goodyear repair plugs. These are installed by first driving the driving pin through the injury from the inside of the tire. Having located the injury properly, the driving pin is pulled from the casing and a small section of the inside of the casing is buffed, after which a coat of self-curing cement is applied. The tire repair plug is dipped in the self-curing cement and when it is dry, it is set into place by inserting the stem into the hole in the needle. Press the head of the plug firmly against the tire from the inside. Finally insert a nail or piece of wire through the hole in the needle and pull it from the tire.

Miscellaneous Repairs. In order to repair cuts in either the tread or sidewall, treat the injury, buff and cement. Line the edges with cushion stock to within ⅛ inch of the exposed surface, then fill in with the tread or sidewall stock, stitching same thoroughly. Trim the edges level with the outer surface of the casing. When curing repairs of this type, a spot machine or a hot plate may be used, making use of a rubber block or small sand bag and "C" clamp. The larger injuries can be cured in a sectional mold with a sand bag and curved iron bar.

Sand blisters are neglected cuts which have been growing worse, owing to friction or unprotected tread and fabric. Treat the injury carefully to be sure that all foreign substances are thoroughly cleaned out. Remove all fabric which has been damaged. Make an inspection for tread separation and see that the fabric left in the tire has not been water-soaked; if it has, it must be dried. In case it is found necessary to remove more than one ply of fabric from the outside of the casing, the tire must be reinforced from the inside. Build up and cure the same as for a cut. The reinforcement on the inside should be the same number of plies of new fabric as were removed on the outside.

U. S. METHOD OF REPAIRING LOW-PRESSURE TIRES

A four-ply round U. S. tire repair unit No. 49-4, shown in Fig. 31, has been developed and is recommended for repairing all injuries in low pressure tires of 6.50, 7.00, 7.50, and 8.25 cross-sectional diameters, in 15-inch and 16-inch rim diameters. Injuries that are too large for the U. S. repair No. 49-4, are usually too large to be economically repaired. The sizes of the plies in the U. S. No. 49-4 repair are 4-inch, 5-inch, 7-inch, and 9-inch. This makes a 1-inch step-off on the two largest plies, as shown in Fig. 32, which provides ample flexibility to the finished repair job.

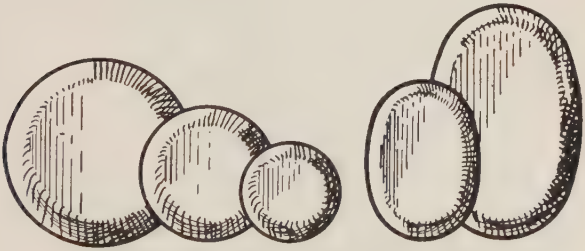


Fig. 31. Sizes of the U. S. Tire Repair Units

Inspection. Low-pressure tires should be given a rigid inspection, even more so than the regular passenger car tire, owing to the greater flexing the low-pressure tire must undergo. The following conditions should be especially looked for: separation of sidewall and tread, separation of bead or carcass, breaks and cuts in carcass, surface cuts in tread or sidewall, and condition as to age and moisture in carcass.

Preparation. When after thorough inspection, the tire is found to be in a condition to justify repairing, dry out the tire thoroughly and proceed as follows. Cut and remove the tread or sidewall rubber from the carcass for at least one-half inch in all directions around the edges of the injury. Remove all additional tread or sidewall rubber that is separated from the carcass. Skive back the edges of the tread rubber on approximately a 45-degree angle. See Fig. 33. Buff the

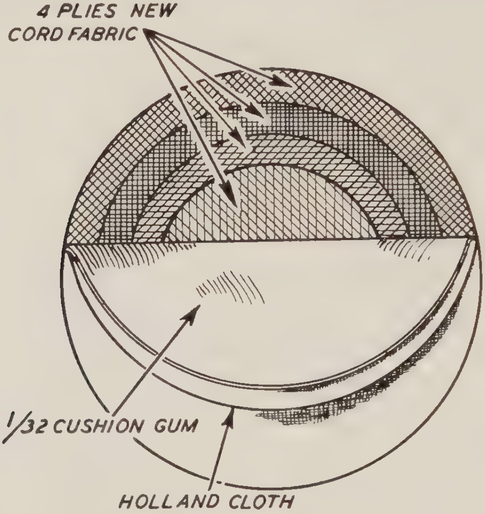


Fig. 32. Construction of the U. S. Tire Repair Unit

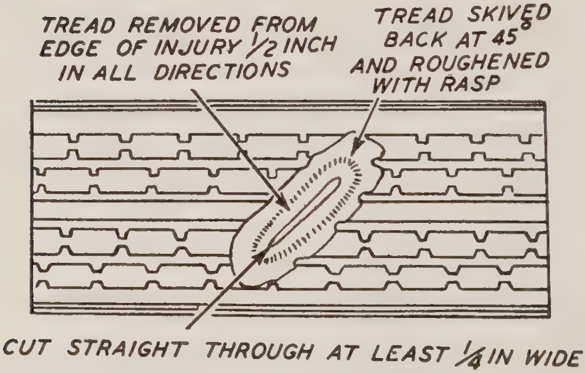


Fig. 33. Preparation of Injury for Repair

exposed fabric with a wire brush and thoroughly roughen the skived tread or sidewall with a coarse rasp. Trim around the injury in the carcass, cutting (not skiving) through all plies. See Fig. 33. Round the ends of the injury, removing all broken or loose cords and eliminating any trace of a V condition. See Fig. 34. Roughen the edges of the injury with a small rasp.

Application of Repair. In order to determine the area in the inside of the tire, to be buffed and cemented, center the U. S. repair unit No. 49-4 over the injury. Use the repair as a pattern and mark an outline on the tire one inch larger than the repair. Buff the inside ply of the tire thoroughly, in the space marked, to remove all lining cement and old rubber. Take care not to damage the cords of the inside ply. Clean thoroughly the inside of the tire, removing all buffing dust. Use high-pressure air or United States Rubber Solvent for this purpose. If high-pressure air is used, make sure that it does not contain moisture. Apply one coat of light vulcanizing cement to the entire buffed area and allow this to dry. This cement is made by using three parts of United States Vulcanizing Cement to one part of United States Rubber Solvent. Apply a second coat of United States Vulcanizing Cement, just as it comes from the can, and allow to dry thoroughly in a drying room, if one is available. In any event, before proceeding with the next operation, make sure that the cement is perfectly dry.

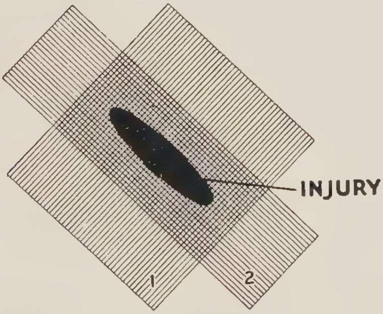


Fig. 34. Injury Cut Out with Vertical Cut and Rounded Ends

Take the U. S. Repair No. 49-4 and, without removing the holland from the cushion gum facing, buff the top side of the repair one inch in from the edge all the way around. Apply a light coat of United States Vulcanizing Cement to the buffed area. Apply $\frac{1}{32}$ inch cushion gum over the injury, allowing it to extend one inch beyond the limits of the injury in all directions. Apply the repair.

Remove the holland from the cushion gum facing of the repair, take the repair between the thumb and fingers, cushion side down, hold the ends together and apply as follows. Apply the U. S. Repair No. 49-4 so that the direction of the cords in the alternate plies of the patch, line up with the alternate plies in the tire, making sure that the cords of the bottom ply of the repair, cross the injury. The direction of the cords in the bottom ply, which are covered with cushion gum, can be determined if it is remembered that they run in the opposite direction to the cords in the top ply of the repair.

For star injuries, apply the repair so that the cords of the bottom ply of the repair, cross the longer break. Stitch the repair down, with the beads of the tire in their natural position. Apply a 1½-inch strip of $\frac{1}{32}$-inch cushion gum to the buffed and cemented edge of the repair. Allow the gum to extend over the outside edge of the repair at least ¼-inch. Stitch down. The use of a 1½-inch strip of cushion gum on the edge of the repair instead of a ½-inch strip, is very important because the cushion gum must extend over the edge of the second-largest ply of the repair.

Building Tread Side of Injury. Place the tire on a tire-last and fill the break in the carcass with cushion gum, covering all exposed fabric with cushion. Do not trap air or over-fill the cavity. Fill the remainder of the cavity with U. S. Tread Gum. Stitch in firmly and trim a little high in the center to insure pressure during the cure.

Curing. Wherever the necessary curing equipment for low-pressure tires is available, cure in the regular manner, using the curing schedule recommended under "Cure." Wherever the necessary curing equipment for low pressure tires is not available, but a 6-inch truck tire sectional mold is available, satisfactory cures can be made by following the method herein outlined.

One set of special bead plates is required for use in the 6-inch truck tire sectional mold. Except for these, which can be made locally at a small expense, no other equipment is required if instructions given herein are followed. To prepare the 6-inch truck tire sectional mold for this work, follow these directions. The first step is to have special bead plates made. This is necessary owing to the small rim diameter of low-pressure tires, namely, 15-inch and 16-inch. The bead plate should be made of aluminum and can be made in any small machine shop. See Fig. 35 for bead plate specifications. The low-pressure tires are to be cured in the mold cavity used for 6-inch truck tires. The cavity for 6-inch truck tires is approximately 6½ inches wide, and the specifications show the bead plate designed for this size cavity. Before making the bead plate,

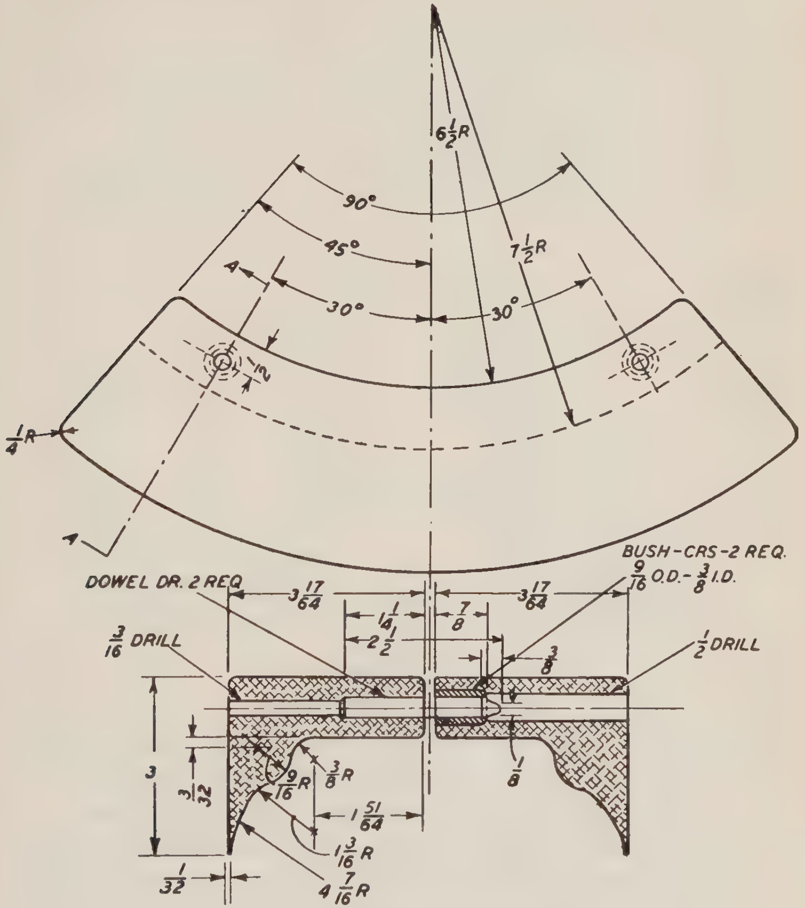


Fig. 35 Bead Plate Specifications

the width of the mold must be checked and the bead plate specifications changed to the width of the mold. All other dimensions will remain the same. The radius will fit both 15-inch and 16-inch rim diameters.

Air Bag. In order to get a good cure on a section repair, uniform pressure must be applied to the repair during the cure. To obtain an air bag of the proper cross-section diameter to fit the tire, use a regular No. 7 U. S. Cord Air Bag, and build up with sections of truck tubes. Truck tubes are recommended; because of their heavy gauge, fewer sections are required. Tubes of a graduated size should be used. Start with a size that pulls over the No. 7 U. S. Cord Air Bag without much resistance, and step up the tube sizes until the air bag is large enough to fit the tire well. After the above recommendations have been carried out, the cure can be made in the regular manner.

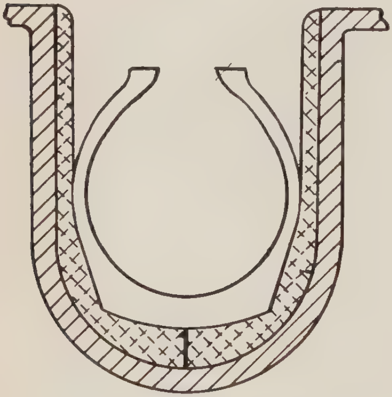


Fig. 36. Mold for Flat Tread

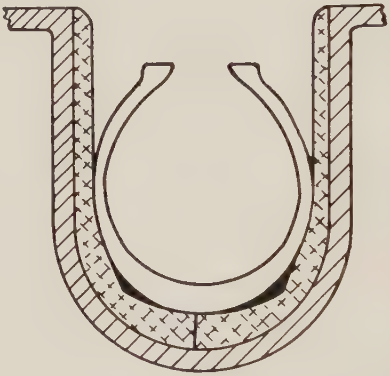


Fig. 37. Round Tread Mold with Matrix

Tread Contour. The tread or section of the tire coming in contact with the road is high and flat on most low-pressure tires. There are, however, some treads that are round. Most of the modern section molds are made for the high, flat tread. When it is necessary to cure round-tread tires in a mold designed for high, flat treads, a special procedure must be followed. Figure 36 shows a high, flat tread in a mold designed for this type of tread.

Fig. 37 shows a round tread in the same mold. It will be noted that the tread is bridged across the mold at the bottom or edge of the tread. If the round tread tire is cured without any support, it will be forced down by the air bag to the shape of the mold, and buckle the repair and carcass of the tire. It will be necessary to make a matrix to overcome this, as follows. Use any uncured repair-fabric scrap; square-woven fabric should be used rather than cord fabric, if available. The fabric must cover the bottom of the matrix for width, and be 3 inches longer than contact point on both ends. Build tread gum on the fabric ply so that it will support the tire, as shown in Fig. 38. Build the ends of the matrix heavier than the center to conform with the radius of the tread at the ends. See Fig. 38. Turn the 3-inch fabric extension up over the ends of the tread gum to hold the gum in place.

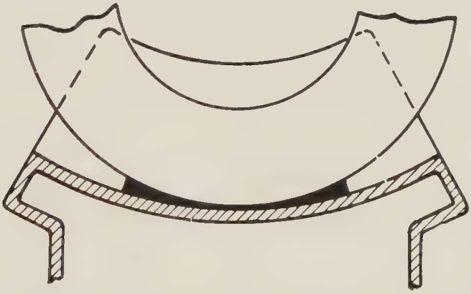


Fig. 38. Matrix to Support Tire in Oversize Mold

Cure. Cure repairs 80 minutes at 35 pounds steam pressure or 281 degrees Fahrenheit. When a rubber matrix is used in the case of a round tread tire, add 15 minutes to the above curing time.

Finishing. Because of the flexing of low-pressure tires, it is very important that the repair be as flexible as possible. The design of the repair, as stated elsewhere, will bring about the required flexibility on the inside of the tire. It is also very important and necessary to make the tread side of the repair as flexible as possible. This can be accomplished by cutting the tread design in the repair with a ⅛-inch emery wheel on a flexible shaft buffer. If a flexible shaft buffer is not available, a knife may be used if care is exercised. Use a coat of tire paint to give the final touch to the repair job. This costs little, makes a finished job, and is good advertising.

CAMEL-BACK FOR RETREADING

Recommended Contours. Camel-back is merely black tread stock, forced through dies of different width, gauge, etc., to conform to the shape of treads used in the retreading of tires. Its use eliminates the tedious labor of building up treads from $\frac{1}{16}$-inch sheet stock and obviates the risk of blisters and separations, which usually follows hand work.

The essential requirement in retreading is to secure a stock of sufficient gauge to insure pressure at all points when used in the deep matrices of heavy non-skid designs. If the design is of $\frac{5}{16}$-inch or $\frac{3}{8}$-inch depth it is absurd to apply a $\frac{1}{4}$-inch stock. While it might appear to flow and fill the indentations of the tread design, it would be found that the knobs, etc., would be spongy and full of air holes, due to lack of pressure.

On the other hand, competition and costs demand the retreader to use a gauge not in excess of actual requirements. Two types of retreading machines are commonly used, i. e. $\frac{1}{3}$-circle molds and full-circle molds. Stocks must be designed for the particular need of each.

In standard practice, two types of camel-back are used. First, the plain, for use on jobs on which the cushion gum has not been removed, or where a separate, new layer of cushion gum has been applied. Second, cushion camel-back, which is simply plain camel-back to which a layer of $\frac{1}{32}$-inch gauge cushion gum has been applied, for use where the entire tread and cushion have been removed or where the tire has been buffed down to the carcass. A third type, plain camel-back with breaker fabric and cushion gum in assembled form, is still in occasional use, but is being quickly superseded by cushion camel-back.

Most retreaders prefer a black cushion gum with camel-back, so that the junction between old and new tread stock may not be too conspicuous. Cushion camel-back is provided with black cushion gum, and the same gum is available in sheet form of $\frac{1}{32}$-inch gauge, in 5 and 10-pound rolls, for vulcanizers and retreaders who desire to buy it in such form.

For like reason, retreaders are partial to black cement and a black vulcanizing cement that has been prepared especially for use with black cushion gum and camel-back.

Cutting=Down. Make certain that the tire to be retreaded is in good condition. Inspect the inside for cuts through the carcass and for separation between the plies of the carcass and between the carcass and tread. A tire that is worn down through one or more plies of fabric should never be retreaded. From the standpoint of future business, do not attempt to retread anything but a good carcass. Remove the old tread. This is accomplished by using a sharp knife.

Place the tire on tire last or arm, which should be attached to a table about waist high. This is the most natural position and the operator has an opportunity to place a foot on the lower side of the bead of the tire to hold it firmly during the skiving operation. After the proper size camel-back for this tire has been decided on, determine how far down the sidewall it will be necessary to skive. Quite a number of makes of tires have a corrugation just below the flexing line, that will help in making a straight cut, and furnish a guide as to how far down to cut on the sidewall. A little practice will soon make it easy to make a straight, even cut, completely around the tire.

Make a cut into the tread, to the cushion between the breaker strip and carcass. Grasp the piece of tread with sufficient tension to stretch the cushion, and cut completely around the tire. Do this until all the tread and breaker strip are removed, being careful not to cut the first ply of cords. It should be borne in mind that owing to the curve of the tire, it is not practical to cut very wide strips at one time. This makes it necessary to go around the tire several times before the old tread is completely removed.

To remove all old cushion from the carcass, use a wire buffing wheel. When holding the tire against the buffing wheel, see that the wheel runs in the same direction as cords in the carcass; not across them. This will avoid the possibility of loosening the first ply and facilitate the quick removal of the old cushion.

After the cords have been buffed clean, the upper edge of the sidewall should be well roughened. Use a rasp if available, if not, use a wire wheel. The angle of the buffed surface of the sidewall should not be sharp, but should be so gradual that it practically follows the contour of the carcass. Featheredge it as fine as possible.

Any nail holes in the carcass can be readily detected after the buffing operation. These should be filled with cushion gum and a No. 1 U. S. Royal Tire Repair placed over the hole on the inside.

Cementing. The tire is now ready for cementing. For the first coat, the cement should be thinned with U. S. Rubber Solvent, about one part of solvent to two parts of cement, and should be well brushed in. The thinned cement will penetrate between and through the cords much better than can heavy cement, and will act as an anchor for the second and heavier coat. The first coat should take about an hour to dry. Allow the second coat to dry thoroughly from 2 to 2½ hours. It should be used just as it comes from the can.

A drying room kept at an even temperature is preferable, not only for uniform drying conditions, but also to keep cemented tires clean. It is important that dust be kept from a drying cemented surface. All items of the U. S. repair material line are manufactured so that they will work perfectly together. It is not advisable to make a repair job using several different makes of materials. The reason is obvious.

Building Up the Tire. The tire, cemented and dried, is now placed on a building arm. Skive one end of camel-back at an angle of approximately 45 degrees, so that the finishing end will overlap the starting end later on. This insures a long, smooth splice. Strip back the holland on the camel-back approximately one foot. It will be noted that stripping the holland back a little at a time, as progress is made around the tire, enables the operator to apply the camel-back without in any way spoiling the tacky surface of the cushion gum. Center the camel-back on the tire. Move the tire around, pulling down the holland as progress is made. At this stage the camel-back should only make contact with the tire in the center.

When the starting point has been reached, the length can be determined. It is advisable to cut the camel-back approximately one-half inch longer than is actually necessary. The one-half inch extra allowance is to enable the operator to make a perfect splice without having to stretch the camel-back. Do not splice the ends at this time. Wash the skived ends with solvent and allow to dry while the camel-back is being rolled down. For rolling down the camel-back, it is best to purchase a pressure roller operated by a crank. In cases where this type of roller is not available, the work must be done by hand. In order to avoid the presence of trapped air, which would prevent adhesion in spots, causing blisters and spoiling an otherwise perfect job, start from the center of the tire and roll to the outside. In this way all air is worked out ahead of the roller, and a perfect union is the result. Roll down the camel-back around the tire to within four or five inches of the splice.

The ends to be spliced will now be dry enough to be put together, after which the splice must be thoroughly stitched down. It will be found that the half-inch surplus stock will take its place upon being rolled down. This excess stock serves the purpose of taking the strain off the splice, and preventing any tendency there might be for the splice to stretch apart when heat is applied.

Curing. The tire is now ready to be cured. Instructions are given in detail for one-third-circle molds. Curing instructions for full-circle molds, differ with the various types.

One-Third-Circle Molds. The following are the sand-bag sizes and tires in which they are to be used for one-third-circle molds. The measurements given are those taken when the bags are empty and flat.

Flat Bag		
Width, Inches	Length, Inches	To be used in Tire Size
4½	52	4.40, 4.50, 4.75 balloon, 28 x 4 and all 3½″ high-pressure
5½	52	5.00, 5.25 balloon and small 4½″ and all 4″ high-pressure
6¾	57	5.50, 6.00 balloon, 32x4½, 33x4½, 30x5 and 33x5 high-pressure
7	57	6.50, 7.00 balloon, 34x5, 35x5, 32x6 high-pressure

Place the proper size sand bag in the tire, and the pressure iron exactly in the center of the sand bag. Before placing the tire in the mold, Fig. 39, be sure the mold is clean. Any little bits of cured stock or cement left in the mold from a previous cure, will leave a roughened and pitted surface on the next tire cured. Steel wool does a very satisfactory job in cleaning the mold. After the mold has been cleaned with steel wool, dip a rag in powdered graphite and give a hard rubbing to the curing surface of the mold. This tends to polish the curing surface and will offset any tendency of tire to stick to the mold.

Now place the tire in the mold and push down solid in the mold. It is very necessary to have the tire straight in the mold. If the first cure is crooked, it will make matching of non-skid design of the second cure very hard, and, in addition, make a bad-looking job. Step back from the mold and see if the tire is in the mold straight. A second method is to have a straight edge of wood or metal to place across the bead. If the beads are level, the tire is in the mold straight.

Place clamps in position for tightening and again see if the pressure iron is in the center of the sand bag. Tighten the clamps. Do not tighten clamps down all the way, but tighten each a little at a time until the clamps are uniformly tight. Bear in mind that good pressure is necessary for perfect vulcanization. After the clamps have been tightened down well, the pressure iron should be tapped several times, the full length of the mold. This settles the sand in the sand bag and insures even pressure over the section to be cured. Now tighten the clamps again until all clamps are down as tight as they will go.

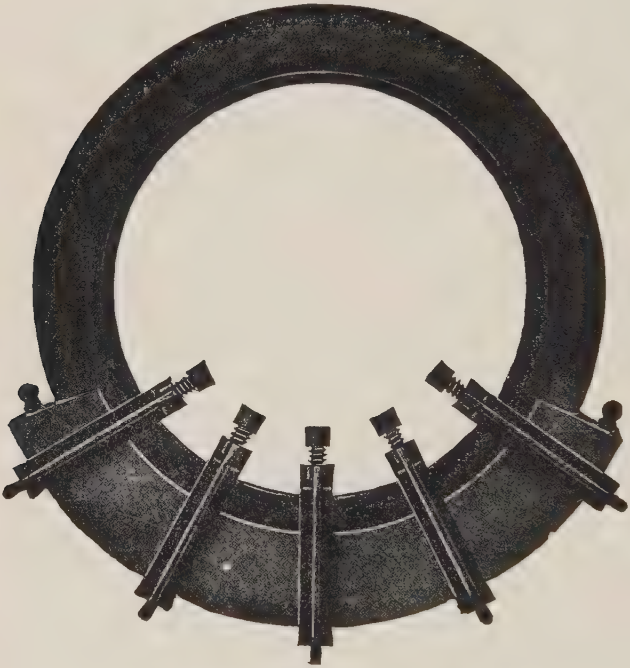


Fig. 39. Retreading Vulcanizer with Tire in Position

After the rubber has become soft, approximately 15 minutes, the pressure iron should again be tapped and the clamps again tightened.

It will be found, where the clamps were tight previously, it is possible to tighten them still more at this time. After the proper time for the first cure has elapsed, remove the tire from the mold. Move the sand bag and pressure iron around the tire so that the lap will be at the lower end of the mold. Be sure to move the tire in the same direction each time. Do not get the tire turned around.

Place the tire in the mold for the second cure, with approximately 5 inches of cured tread in contact with the matrix. Grasp the tire by the beads with both hands. Pull the tire down in the mold snugly at the lower end, at the same time move the tire toward the end of the mold. The operator can feel the non-skid design drop into corresponding design in the matrix. It will also be noted that the tire will be harder to move after dropping into the non-skid design. Be sure to tighten the clamp over the matched section first. This prevents the possibility of the tire slipping while the other clamps are being placed in position. Use the same care in clamping down and follow the same procedure as in the first cure. When the second cure is completed, remove the tire and move the sand bag and pressure iron as in preceding cures.

Place the tire in the mold for the third and last cure. Remember, matching is done at the lower end of the mold, as was the case in the second cure. Care must be taken to see that a lap of approximately 2 inches is made at the upper end of the mold. This is to insure a complete cure around the tire. Match the design and clamp down as in preceding cures. When the third and last cure has been completed, remove the tire from the mold. The result will be a perfectly retreaded tire.

Dressing Up the Tire. Before the tire is turned over to the customer, clean all dirt which the tire may have picked up from standing on a dirty floor or from being handled.

A very effective finish is to paint the entire outer surface of the tire with tire gloss. This puts a finishing touch on a good job. A good appearance, as well as efficient workmanship, goes a long way toward developing future business.

The following are some high points regarding retreading of tires that it would be well to keep in mind. Never retread anything but a good carcass. Be sure to cut off old breaker fabric. Do not cut pieces of cord out of the carcass during the skiving operation. Buff the carcass clean, being sure to remove all old cushion gum. Be sure and have the part of the sidewall that comes in contact with the camel-back, well buffed. Be sure the cement is brushed well into the carcass. Be sure the cement is properly dried. Keep the cemented tires in a clean place, out of the dust. Be sure the camel-back is placed in the center of the tire. Be sure there are no air blisters left after the camel-back has been rolled down.

FULL-CIRCLE RETREADING

There are two fundamental methods of retreading, these being the full retread and the capping method. In the full-retreading method, the old tread rubber is completely removed from the tire and replaced by new material. In passenger car tires it is not necessary to replace the breaker. Ordinary "cushioned camel-back" of the proper die contour, which consists of cushion and tread gum, will give excellent results, as previously described.

Capping. Capping is the method of preparing a tire for retreading by merely roughing up the old tread rubber, applying one or two coats of cement and then a very small amount of new tread rubber. It differs from the full retread job, because in the full retread job the old tread rubber, breaker strip, and cushion, along with all nails, glass, or other foreign matter, are removed and the carcass of the tire may be thoroughly inspected from both the inside and outside.

While capping costs less to do than full retreading, and can readily be done, there are so many things that can go wrong with a capped tire that it is strongly urged that operators refrain entirely from practicing that method. The difficulties in capping lie in the fact that the additional heat required in vulcanizing very often causes separation at the old breaker and cushion left on the tire; also, it is practically impossible to remove foreign matter of various kinds which is left in the old tread rubber and which will cause failure of the recapped tire. In short, the old tread rubber does not serve as a proper foundation for the new tread material and it should be removed.

Preparing the Tire and Curing the New Tread. Briefly described, the operation of retreading a tire, using Heintz Full-Circle Mold Equipment is as follows. First, the tire is removed from the rim and thoroughly inspected to determine that the carcass is sound and worth retreading. A thorough inspection at this stage will avoid waste of labor necessary in cutting down and preparing tires which might not be proper material for retreading. The old tread rubber, cushion, and breaker are removed from the tire. This is usually done by means of a large rubber cutting knife. For an experienced operator, the time required will run from approximately six minutes on a small passenger car tire, to perhaps an hour on larger truck tires. A few operators have installed a machine for removing the tread. This machine is usually built by converting an old type of tire building machine into a tread removing machine. The machine saves considerable labor. A vulcanizing room is shown in Fig. 40.

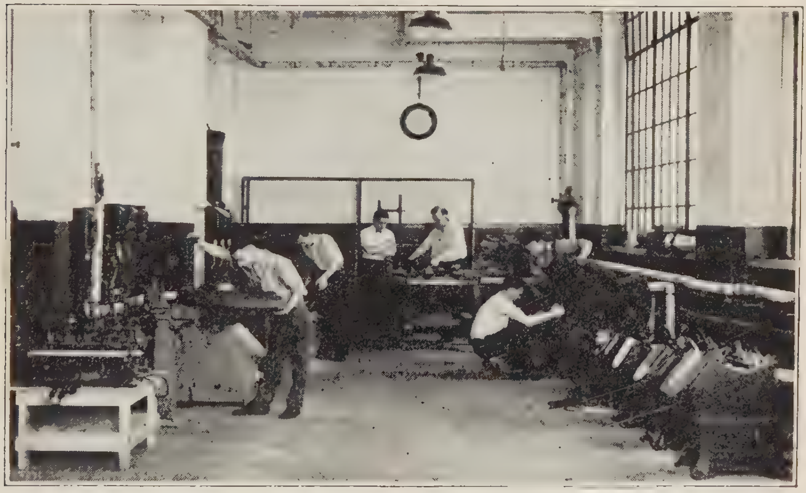


Fig. 40. Vulcanizing Room Showing Retreading Equipment

The tire is thoroughly buffed down to the cords, at the tread section, to provide a good, clean surface for the new rubber to adhere. Two coats of cement are applied to the tire, allowing time for each coat to dry thoroughly. The new tread rubber of the proper thickness and contour, as recommended, combined with cushion (or cushion and breaker, in case of truck tires) is then applied to the tire, and the tread is thoroughly rolled down to eliminate air pockets. Complete data as to contours of camel-back are furnished in the instruction manual, and the operator, of course, must see that the proper size of rubber is applied.

A curing tube is now placed in the tire. The tire is mounted on a standard road rim of the size recommended. Curing tubes are available from the tire manufacturers and are made up especially for use with this type of equipment. They have an average life of 100 or more cures. The mold and matrices, having previously been heated, are ready for use. The upper section of the matrix is removed and the tire is inserted in the mold. Then the upper section is replaced and thoroughly clamped into position. The tire is then inflated with air, according to the pressures recommended in the instruction manual. The tire is allowed to remain in the mold for the length of time recommended by the manufacturer of the new rubber used. The time usually varies from one hour for a small passenger car tire, to two and one-half hours for a large truck tire. After curing, the air pressure is released from the tire. Then the clamps on the tire treader are removed, along with the upper sections of the matrix, and the tire can be removed from the mold. In case of truck tires, it is necessary that some means be provided to assist in removing the tire. This is usually accomplished by the use of a 2000-pound chain hoist.

The tire is now demounted and the curing tube removed. It is necessary to trim the tire of any overflow material, such as slight rinds, left at the joints of the matrix or the small vents in the matrix. A small amount of labor expended in buffing the tire slightly, will result in a tire having very close to new tire appearance, and will pay dividends.

Construction and Operating Principles. The two sketches shown in Figs. 41 and 42 are cross-sectional views of a tire treader, showing the mold body, matrix, sidewall retaining rings, rim, tire, and air bag in operating position. Fig. 41 illustrates how the sidewall retaining rings function in case of a normal size tire. Fig. 42 shows the same assembly of parts, but with a larger tire in the mold.

The sidewall retaining rings, as you will note, constitute cold extensions of the heated matrix, and serve to prevent distortion and marking of the tire at the edge of the matrix. The rings also perform the function of concentrating the fullness of an oversize tire between the flanges of the rim and the edges of the rings. This provides the feature of automatic adjustability for tire size variations.

It will be noted that the mold operates in a horizontal position and that the lower matrix section and sidewall holding ring will lie in position without requiring any mechanical fastening. If it is desired to change the matrix for curing another size of tire, the matrix spacer section or the entire matrix can be changed very quickly.

The mold body is heated by steam in the conventional manner. A thermometer at the side of the mold, indicates the steam temperature. Perfect circulation of steam is attained throughout the entire mold body. The inner bore of the mold is machined to very close limits and the matrix sections are likewise accurately fitted to the mold bore. All sections of the matrix are therefore uniformly heated. No flexible steam joints or gaskets are required.

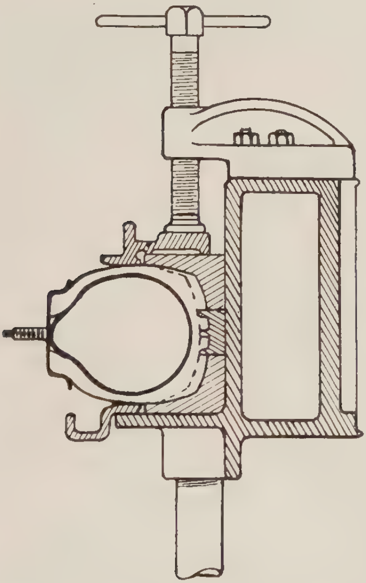


Fig. 41. Normal Size Tire. No Sidewall Bulge

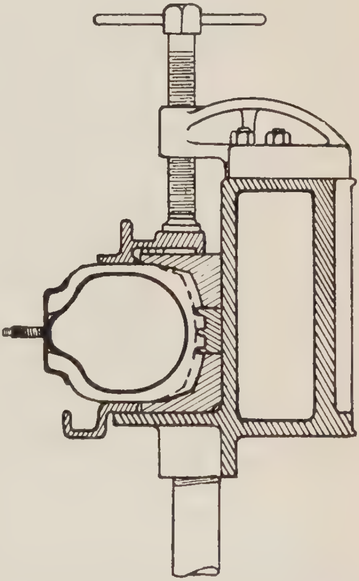


Fig. 42. Oversize Tire. Note Sidewall Bulge

The operation of placing a tire in or out of the mold, takes only three to five minutes. On heavy truck tires, however, it is essential to locate a chain hoist above the mold to assist in handling the tire.

The mold body is very heavily constructed, and is amply able to withstand all stresses placed on it in actual operation. Each mold is tested to 450 pounds of cold water pressure before being assembled. The molds are packed in asbestos insulation to reduce heat radiation and operating cost, and come complete with floor standards, eliminating the necessity for building special benches. Suitable steam inlet and return connections are provided.

The matrix clamping device is simple and effective as well as quick in operation. It clamps the matrix sections and sidewall retaining rings in positive alignment. Being free from any engagement with the rim, it allows the rim and tire to float in the matrix and sidewall ring assembly, thereby automatically placing the tread in the center of the tire.

An Especially Designed Full-Circle Retreading Machine. The problems involved in retreading and in building a tire are different, a fact often overlooked in retreading equipment. A tire manufacturer can build a mold to fit a tire of the exact dimension and design that he proposes to manufacture. His mold will not fit any other size of tire. He can design it for maximum utility and efficiency in a tire factory, yet this same mold will fail entirely to function as a general purpose retreading machine, because it lacks the features of design which a retreading machine must have.

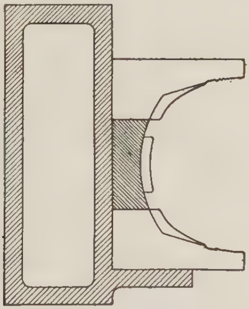


Fig. 43. Mold with 3-Piece Matrix

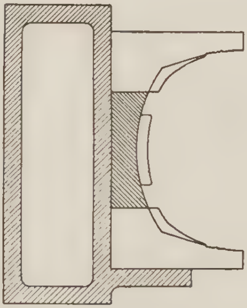


Fig. 44. Same Mold with Wider Center Spacer

In any type of full-circle retreading machine, it is necessary to have numerous changes in matrix dimensions, if a number of tire sizes are to be handled. These changes in dimension can be accomplished first, by providing a separate matrix for every change in matrix dimension; or second, by providing a fewer number of matrices and using matrix spacers to vary the cross-sectional width of the matrix assembly. Since matrices are expensive to manufacture, for very practical reasons all full-circle retreading machines use spacers of some kind.

With the one-piece mold and multiple-piece matrix construction, as used in the tire treader, good results are obtained. Fig. 43 shows this mold and the three-piece matrix in cross section. Note that a spacer is used in curing every size of tire and that the entire center portion of the tire is molded in the spacer. The spacer may be of any width desired because it receives the same heat from the mold as do the two matrix sections.

If a larger tire is to be cured than will fit in the matrix and spacer assembly shown in Fig. 43, then a wider spacer may be used, as shown in Fig. 44. Note that in Figs. 43 and 44 (narrow or wide spacer), a uniform tread contour is maintained, and there is no flat spot in the center of the tread.

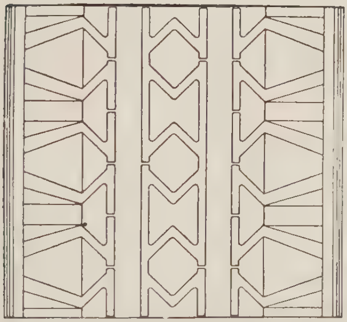


Fig. 45. Design for Tread

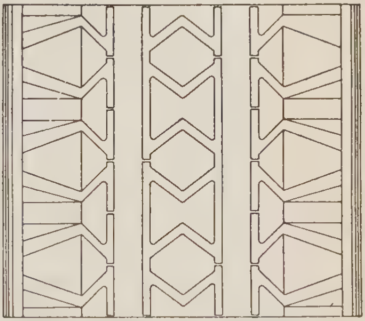


Fig. 46. Tread Design Produced with Wider Spacer

Tires cured in the tire treader have a proper tread contour, because with the use of either narrow or wide spacers, the tread curvature of the spacer can be blended with the curvature of the matrix sections.

Fig. 45 illustrates a tread design produced in a tire treader matrix using a narrow spacer. Note the good design distribution.

The tread design, Fig. 46, is reproduced in the tire treader with the same matrix as shown in Fig. 45, except that a wider spacer is used for a larger tire. Note that the design of the center portion of the tire blends with the design of the shoulder.

It is possible to secure new sizes of matrix spacers for the tire treader, as may be required to handle new tire sizes properly falling within the capacity of a given matrix. The width of these spacers may fall within quite a wide range, and still blend properly as to ornament distribution and cross-sectional contour. It is also possible to vary the groove depth at the center of the tread with Heintz matrix construction. An example of this is found in the truck tire matrices where heavy-duty tires are retreaded with deeper treads than bus balloons, the change in tread depth being handled in the spacer design.

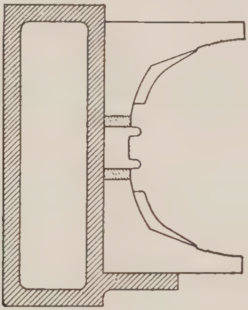


Fig. 47. Oversizing Strips

In the curing of heavy-duty and bus balloon tires, it has been found that because of extreme stiffness of these tires and wide difference in manufactured dimensions, oversizing strips are desirable in curing oversize tires. One very simple measurement is made of the tire before it is placed in the mold, and if it exceeds the dimension of a normal size tire, it may be cured perfectly with the use of these oversizing strips, Fig. 47.

BRAKES

BRAKING SYSTEMS THEORY

While motorists are keenly concerned about their ability to control automobiles, decelerating them rapidly from the higher driving ranges to safe speeds, they care but little about the type of equipment used to effect this deceleration. Their demand for rapid deceleration, however, is imperative; and this demand has brought about the standardization of passenger-car brakes, and also, in a rather marked degree, the standardization of the brakes used on heavier motor vehicles. Today, practically all braking systems are of the internal or enclosed type, Fig. 1. Shoes are rigid rather than flexible and, of course, are expanding from within the drum rather than contracting from without.

More and more, motorists are demanding that the pedal of the car be easy. They also expect rapidity of deceleration and at the same time a braking effect soft and positive. In short, they expect a rapid velvety braking action.

Except for the occasional use of external bands on the transmission brake drums, all passenger-car brakes are of internal expanding design. This means that all braking action is dependent solely upon the friction developed between the brake lining and the surface of the brake drum. Engineers select linings of varying degrees of frictional coefficient in order to secure the most satisfactory operation of their equipment.

Starting with this fundamental of braking design, engineers have deviated considerably in practice as to the method of applying the power necessary to secure quick and efficient brake operation. For many years, almost all engineers depended solely upon foot or manual power for the control of brakes. More recently, however, power operation of various types has come into use.

At present, two methods of controlling or actuating the brake shoes are in general use. The older method is, of course, the mechanical one; the other method, which has been proved by long periods of use, is the hydraulic.

Mechanical Brake System. Fig. 2 illustrates the fundamental units required for operation of a four-wheel mechanical braking system. This drawing is presented because of the simplicity of details. The reader will need to remember that irrespective of the mechanism used, the final results are quite similar to that secured from the elementary system. The end bearings shown in Fig. 2 are used to support the cross shaft on which are mounted the levers connecting brake, pull rods, pedal, and hand brake pull rods. A steady bearing is mounted at the center to prevent bending of the shaft under load.

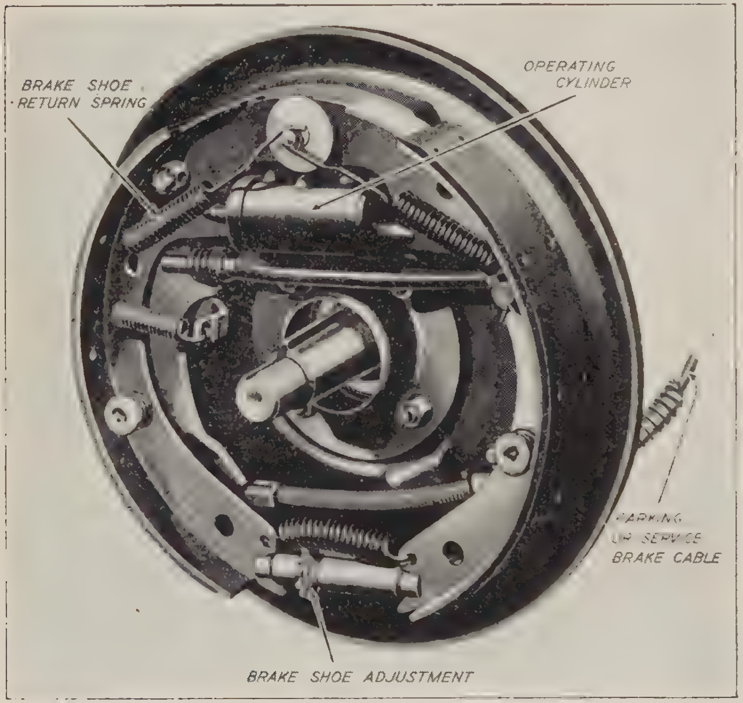


Fig. 1. Oldsmobile Rear Wheel Brake Shoes Are Hydraulically Operated, as Service Braking and Cable Operated for Parking
Courtesy of Olds Motor Works

When the foot pedal is depressed, the cross shaft is turned in its bearings. This throws the vertical levers near the outer ends of the cross shaft forward on the top of the shaft and rearward on the bottom of the shaft. The pull rods to the rear brakes move forward and the pull rods to the front brakes move rearward, thus applying the shoes in the four-wheel brakes at the same instant. To allow the operation of the foot linkage without interfering with the hand brake linkage, an overrunning slot is used in the clevis connecting the hand brake pull rod with its lever on the cross shaft. When the hand brake is set, the pedal moves forward as in its normal use. Formerly, many braking systems incorporated additional shoes for the hand brake and the hand brake was in no wise connected with the foot or service brakes. Later developments make use of the same system with dual control, using four sets of shoes only.

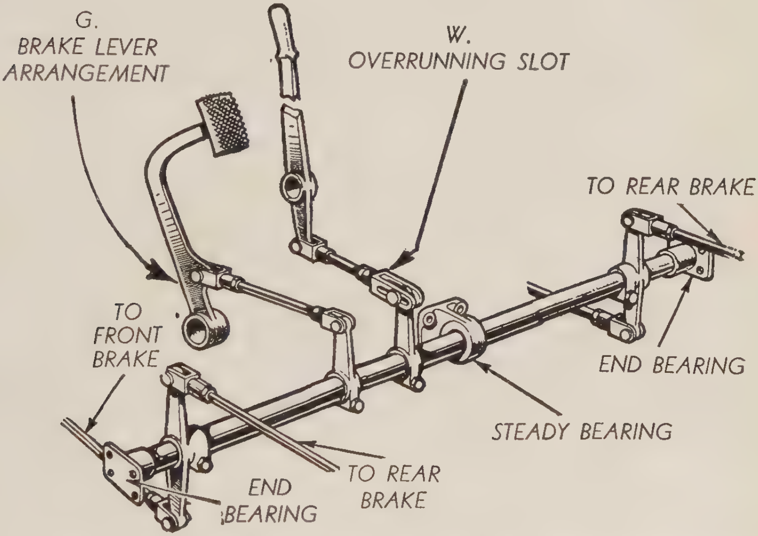


Fig. 2. Hook-Up for a Four-Brake System Where Both Hand Lever and Foot Pedal Operate on the Same Cross Shaft and Linkage

Lincoln-Zephyr Brakes. Fig. 3 illustrates the brake hook-up of the 1937 Lincoln-Zephyr car. The same principles of operation are in-built as those illustrated in Fig. 2; that is, the hand brakes and the foot brake pedal operate the same set of shoes, the foot brake being used of course for ordinary service braking when driving and the hand brake for parking. When the foot pedal is depressed, the cross shaft is rotated with the result that the brake cables connecting the two front brakes are moved backward and the brake cables connecting the two rear brakes are moved forward. The outer ends of these cables are connected to the brakes through flexible conduit. An equalizing effect is secured as between the two rear and the two front brakes in this construction.

The hand brake is mounted in the cowl in an inverted position as shown. This also is cable operated through a flexible conduit. In all cases where cable in conduit is used for mechanical operation, it is necessary that each end of the conduit be firmly attached to a rigid member so as to secure proper action. The conduit between the two points of attachment is free to bend and flex, but since the overall length of the cable is not changed with this flexing, the effect secured is as though a straight braking rod was utilized. This arrangement permits the full movement of the axles with reference to the car frame and springs without in any wise affecting the brake adjustment. In the older designs where rigid brake rods were utilized, the loading of the car frequently affected the efficiency of the brakes, owing to a change in the distance between lever eyes. The cable controlled brakes are very much simplified over the rigid pull rod type, having fewer parts requiring adjustment and lubrication.

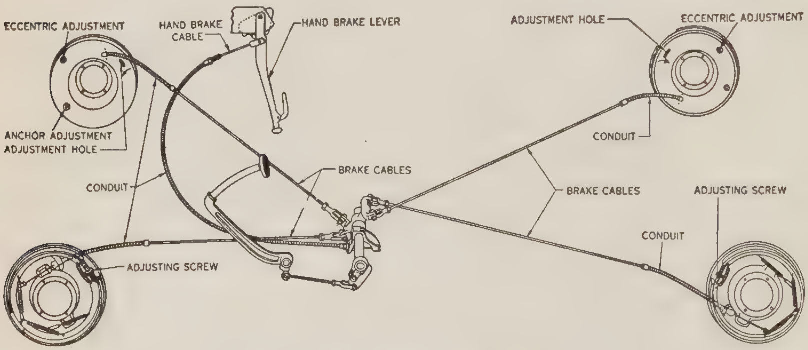


Fig. 3. Lincoln-Zephyr Brake Hook-Up

Hydraulic Brake System. The essential units of a hydraulic braking system are shown in diagrammatic form in Fig. 4. The only parts not illustrated are the front brake shoes, which are identical with those shown for the rear. It is understood, of course, that the hydraulic action has to do only with the application of the power developed by the operation of the foot pedal, which in itself is me-

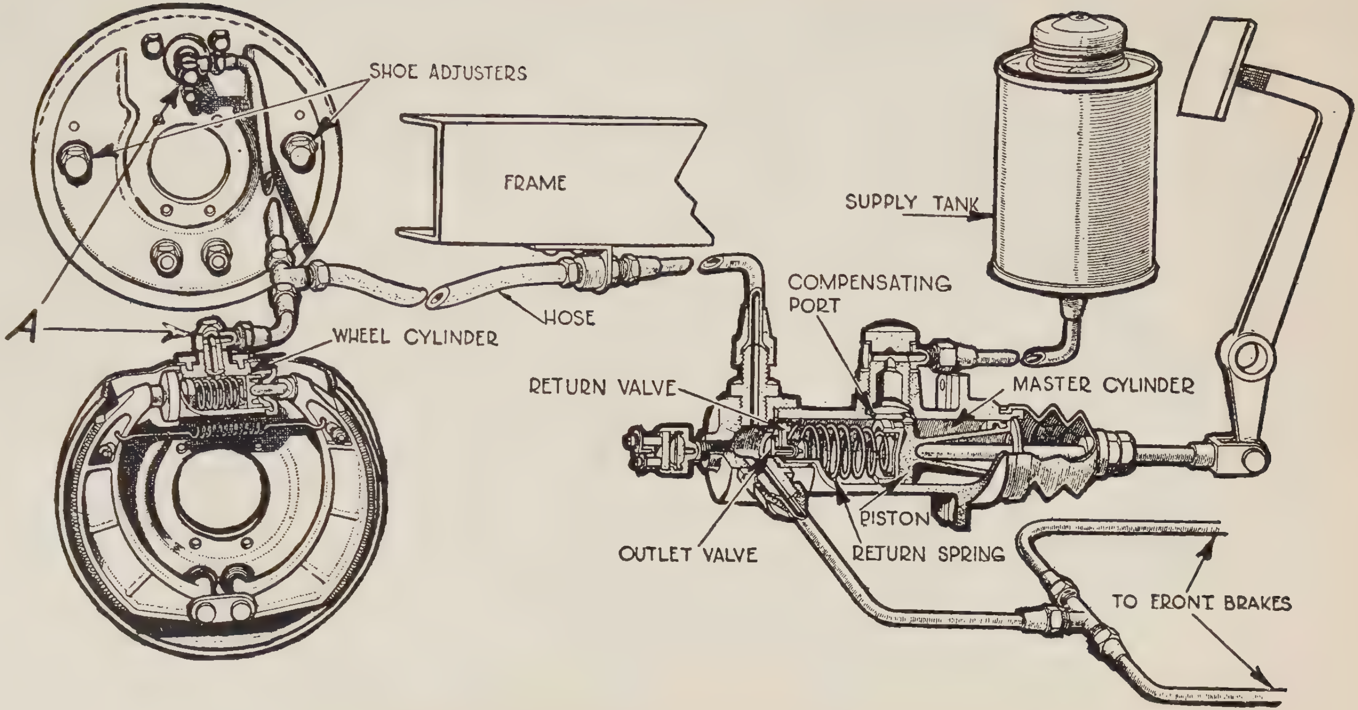


Fig. 4. Diagrammatic Layout of a Hydraulic Braking System

chanical, through to the piston of the master cylinder, at which point hydraulic power is developed. This power or force is sent through the tubes to the cylinder within the wheels, where the pistons within these cylinders are expanded and result in giving a mechanical action to the internal shoes, expanding them against the surface of the drum. The principle of operation of the hydraulic brake is simple and easily understood when it is remembered that the pressure, developed by the action of the piston within the master cylinder on the fluid contained therein, is exerted in a like amount in all parts of the hydraulic system. For instance, if the pressure developed is fifty pounds per inch on the piston head in the master cylinder, a like amount of pressure is exerted on each inch of the piston heads in each of the wheel cylinders. By making use of this principle, it is possible to have considerable force exerted to set the brake shoes to the drums while the driver is required to do a relatively light amount of work.

There has been some cooperation between the builders of hydraulic brakes and the brakes ordinarily spoken of as servo brakes with the result that comparatively light pedal pressure is necessary to set up the servo action within the brake drums, the braking effect being secured by means of the initial hydraulic and the secondary or following servo action, which is also made use of in practically all so-called mechanical brake designs.

Servo Action. The so-called manual or foot application of braking power without aid, other than simple levers, has been found to be insufficiently positive for the average driver. In order to assist the application of the braking system by means of manual effort, engineers have carried the braking system through a very large number of experimental stages until most braking systems can be said to be standardized within the realms of several well-known principles. One of these is the servo principle. By servo, we mean self-setting or an action which tends to help set the brake shoes when the manual application of them is first started. While there are a considerable number of variations of this servo action, in the main it is developed by means of the application of the lining on one of the shoes within the drum to the revolving drum in such a manner as to cause the shoe itself to tend to turn with the revolving drum. Naturally, of course, some means is used to limit the amount of rotation of the shoe, so that as it is withheld from rotating, the energy thus imparted in this effort is utilized to set or apply the other shoe or shoes within the drum to the work of braking or stopping the car. This means that in most cases one shoe is so connected to a second shoe as to apply the power developed by the servo action to this second shoe (and sometimes a third), thus leaving the manual effort to the accomplishment of this purpose for which the system is designed, that is, setting the primary shoe only.

Naturally, the service man must know something of the design of the various systems. If he does not understand this, then it is likely that he will apply a grade of lining to the braking system which will not give proper servo action. The servo action may either be less than it should be or more than it should be. In the latter case, of course, this will result in locked wheels. If the friction coefficient of the lining applied to the primary shoe is too light, then the braking action or the foot-pedal pressure will be so great as to make for hard braking.

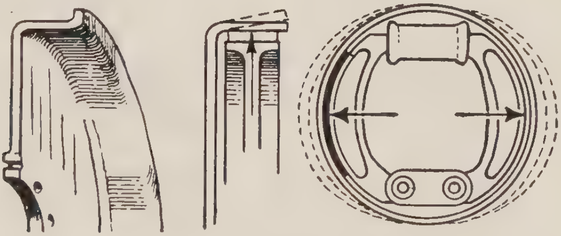


Fig. 5. Thin Drums Go Out-of-Round Under Heat and Load

Brake Drums—Friction. Doubtless the high lights of brake design shine around that element known as friction and the combination of the proper coefficient of friction in the lining together with the proper coefficient of friction within the drums of the brake. While cast iron has long been recognized as the ideal substance for braking efficiency, weight has been a deterring factor. For many years, stamped drum plates had been used almost altogether. Of course there have always been exceptions where the expense and weight of cast-iron drums were not deterring factors. The trouble with the pressed steel drum has always been the tendency of the drum to start cutting or picking up particles of grit or steel in the lining, which in turn would cause cutting of the steel drum and expansion under heat, as shown in Fig. 5. At present there is a decided turn toward the use of a cast-iron lining within a steel drum, as shown in Fig. 6, thus securing an ideal wearing surface along with relatively light weight. While it is claimed that these drums will give very much greater life to lining and drum surfaces than the old steel drum, it is also true that many cars in use are equipped with steel drums and these must be serviced.

An efficient braking system means one which combines a proper coefficient of friction of the lining material and a lining material mounted on shoes so designed as to apply this material properly to the internal surfaces of the drum in a concentric or even manner and, further, proper drum material to work well with the lining used.

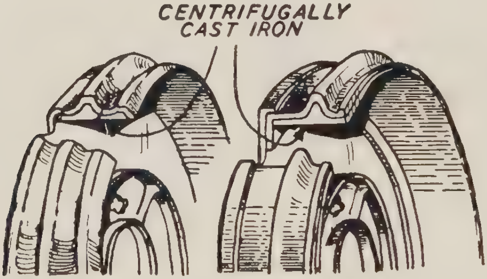


Fig. 6. Cast Linings for Steel Drums Are on Many of the New Models

Brake Shoe Design. Almost without exception, brake shoes are constructed in rigid form so that the lining may be ground and the unit may be fitted within the brake drum. In the case of the steeldraulic brakes, a combination of a flexible and rigid inner shoe is used so that a servo action may be generated by the flexible section and transmitted in positive manner to the rigid section. This design is illustrated in Fig. 7. This might be said to be a one-shoe assembly with several rigid sections from which the same type of actions is secured as from a two- or three-shoe assembly.

The principle of the three-shoe internal expanding brake is one of servo action, the primary shoe being thrown outward by cam or lever action until it contacts the surface of the revolving brake drum, which action has the effect of tending to carry the primary shoe around with the drum so that the force thus developed is transmitted to the secondary shoe, which serves to stop the primary shoe against rotation. The power thus developed and transmitted to the secondary shoe, which has one end fitted against rotation, serves to throw the shoe against the surface of the revolving drum in a very positive manner, thus resulting in a relatively slight amount of manual effort being required to operate the foot pedal to secure quick and powerful braking action.

A typical form of a three-shoe braking system is illustrated in Fig. 8. Here it will be noted that the third shoe is operated by the action of the cam simultaneously with its action of throwing the primary shoe outward against the surface of the braking drum.

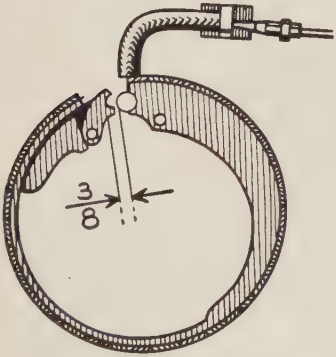


Fig. 7. Steeldraulic Brake Shoe Design

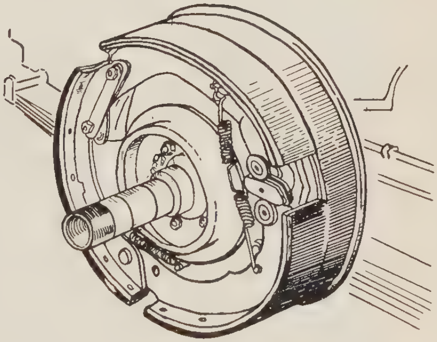


Fig. 8. Three-Shoe Servo Brake

The most commonly used form of a two-shoe brake drum is the duo-servo type illustrated in Fig. 1. In this design, each shoe in turn becomes the primary shoe and, likewise, the secondary or servo-operated shoe. Whenever a car is proceeding forward and the brakes are applied, the shoe toward the forward end of the car receives the thrust and is carried around with the revolving drum a very slight distance, of course, before it affects the secondary shoe, which is the one to the rear of the car, throwing it outward in positive fashion against the surface of the drum and securing powerful action. In case the car is being driven in reverse and the brakes applied, the action of the shoe is likewise reversed, this being made possible by the special design incorporated in its construction.

The four-shoe brake design, Fig. 9, is utilized in the case of some of the General Motors models, this being known as the Huck brake. It is in reality a six-brake system, four of the brakes being set by means of the operation of the foot pedal, and the other two brakes, which are additional pairs of shoes in each of the rear wheels, being operated by means of the hand brake.

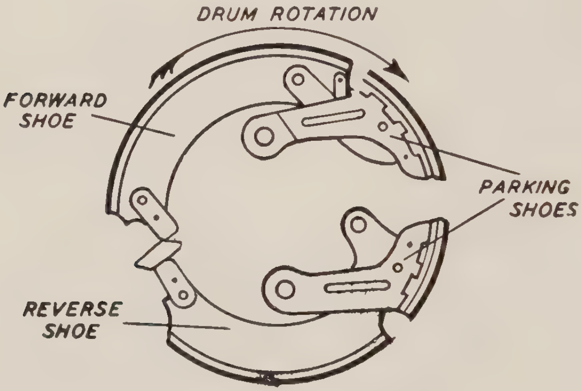


Fig. 9. Huck Brake Shoe Design

AIR BRAKES—OPERATION AND SERVICE

The air brake has been fitted to automobiles over a considerable period of years and every mechanic should know the principles involved in the air brakes. There are two types of brakes. One type operates on the principle of compressed air, that is, it works above normal air pressure. The other type, which is sometimes spoken of as a booster brake or vacuum brake, works on the vacuum principle, and utilizes a pressure lower than the normal 14.7 air pressure.

Pressure System of Air Brakes. In the case of the pressure system, which is used on some buses and trucks, an air pump is provided on the engine which is used to compress air and force it into the air tank. This air tank has a sufficient capacity to allow for a reserve above that normally required. A relief valve permits the pump to operate continually without the tank reaching too high a pressure.

When setting the brakes, the operator merely opens the air valve, which permits the air under pressure to be admitted to the air cylinders. These air cylinders are not necessarily in the form of a cylinder such as is used in the hydraulic brakes, but are rather in the form of a housing within which a flexible diaphragm has been mounted. In this diaphragm is located the piston, which has a movement of only a few inches at the most. The pressure admitted to the cylinder forces the diaphragm against the piston head so that the piston rod is forced outward, and thus the braking action is secured. Fig. 10 illustrates this principle. Naturally considerable force is available for braking, since the operating pressure may be as high as 100 pounds per inch.

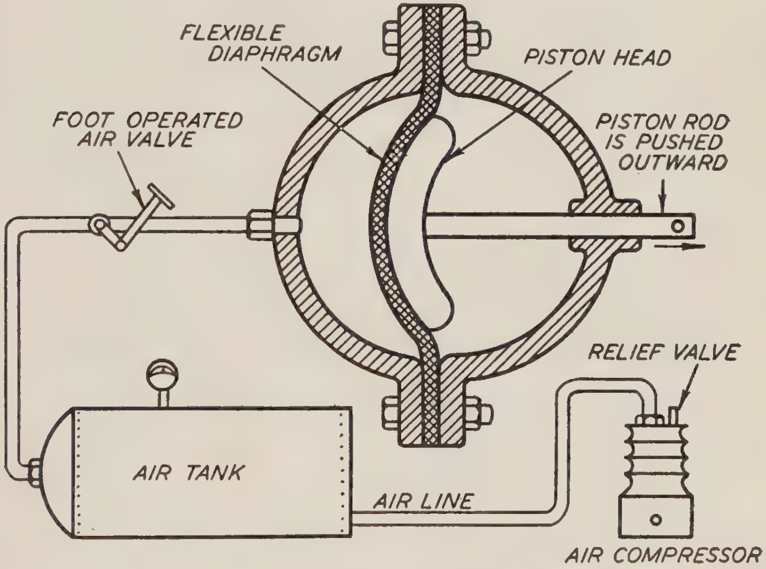


Fig. 10. An Automotive Air-Brake Plan—Pressure Type

Compressed Air Brakes. The use of compressed air for a braking system is popular with heavy-duty trucks and tractors for highway transportation units, also for buses. In this case, an air pump is incorporated with the engine so as to provide a source of compressed air, this being stored in a tank and released to the power lines by means of a pedal similar to an accelerator or throttle pedal. A system such as this is illustrated in Fig. 11. The compressor is engine driven.

Stored air is led through tubes to the four-wheel cylinders, each one of which sets one pair of brake shoes. Special regulating valves are used.

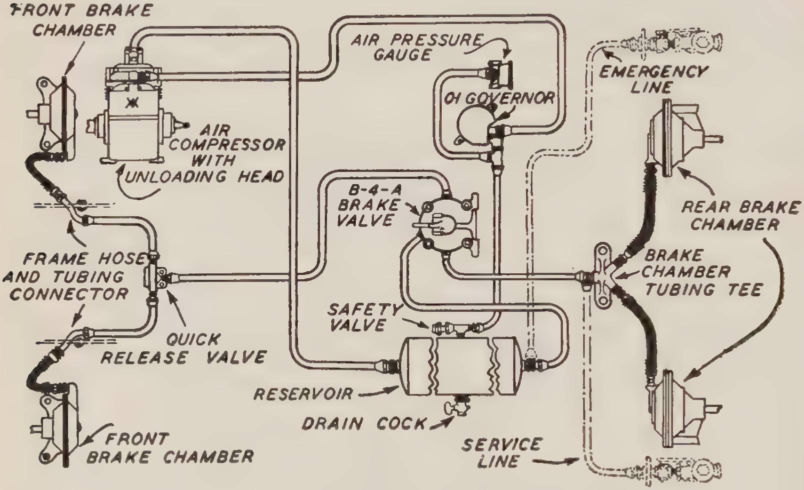


Fig. 11. Brake Equipment for Truck or Bus with Four-Wheel Brakes
(Dot and dash lines show connections on truck for trailer)

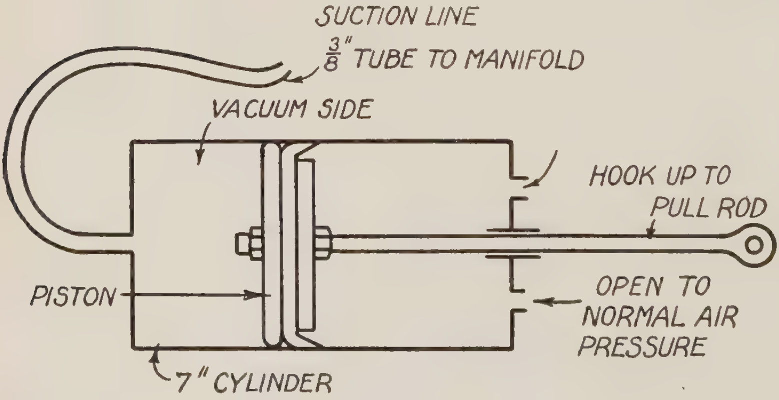


Fig. 12. A Simple Vacuum Brake

Vacuum System of Air Brakes. The vacuum principle has been made use of in a considerable number of cases in reference to passenger-car brakes. In practically all instances the system is so designed as to act in conjunction with the normal pedal action; the main feature being that normal pedal action brings into use the air or booster brake. Fig. 12 illustrates a simple vacuum brake.

The fundamental principle involved is simple to understand if the mechanic understands the normal air pressure and what a vacuum really means. Normal weight of air or normal air pressure is 14.7 pounds per square inch at sea level. If the air is withdrawn from a cylinder and a piston is interposed between the external air and that portion of the cylinder from which the air is withdrawn, then a force equal to some part of the 14.7 pounds per square inch which is present forces the piston toward the point of vacuum. In no case is the full pressure of 14.7 pounds available for the simple reason that the vacuum is secured by connecting the vacuum side of the cylinder to the intake manifold of the engine. Possibly the highest pressure ever available would be around 10 to 12 pounds per inch. This would be only when the car is coasting along in high gear with the carburetor throttle fully closed. The pistons on the engine would be pumping the air away from the intake manifold and, with a closed throttle, very little air could be admitted so that a high vacuum would be secured. The force then available to set the brakes is the normal air pressure acting against the piston. Since but 10 to 12 pounds of pressure is available the piston-head area is made relatively large. A 7-inch cylinder will develop a maximum pulling force of approximately 500 pounds.

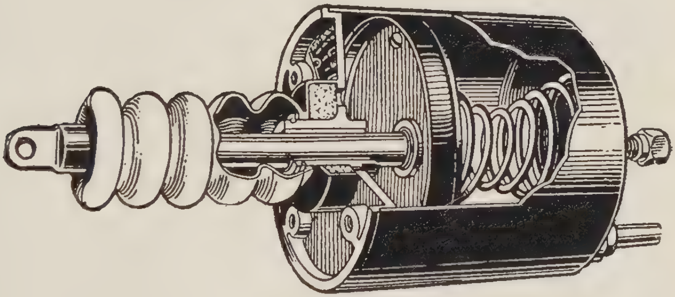


Fig. 13. The Vacuum Brake Cylinder Is a Power Brake

Commercial Uses of Vacuum Brakes. The system, Figs. 13 and 14, is so arranged that when the foot pedal is applied, the valve is opened and air within the cylinder is exhausted into the engine. The rear side of the piston and the cylinder of the vacuum brake are open to atmospheric pressure, so that when the pressure is removed from the forward portion of the piston, atmospheric pressure, rushing in at the back of the piston, causes pressure to be developed and force exerted on the piston, with the result that brakes are applied. This system has had wide acceptance both in foreign countries and in America.

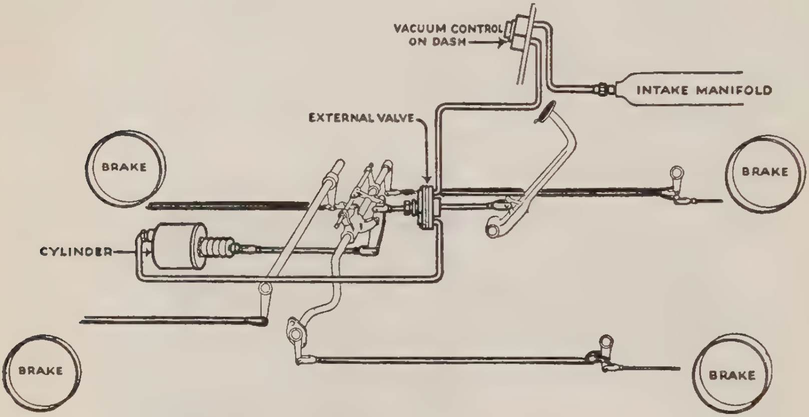


Fig. 14. A Typical Vacuum Power Brake Hookup

BRAKE SERVICE

New Service Equipment and Methods. Snappy engines, rapid acceleration, four-wheel brakes, and rapid deceleration are the standards of mechanical performance the car owner is most concerned in. Unfortunately he is less concerned about the stopping part than he should be. Fig. 15 shows the type of brake service station which makes for safer motoring.

Scientifically-designed brake-testing equipment is now available for service shops as well as for the factories. This equipment is available in many styles. It ranges in price from a few dollars up to several thousand, but science has played its part in the design of even the most simple and least costly. No shop featuring brake service should be without some form of test equipment which records braking effort in an easily understood and real fashion, so that comparisons and equalization may be effected.

Fig. 15. A Brake Service Station
Courtesy of the Automobile Digest

There are on the market and in use in many service stations some very splendid brake-drum machine tools. Car owners want perfect brakes. The service man is equipped for giving the car owner what he wants, but in some cases the drums are too thin to stand machining. The only remedy in such cases is to put the customer to the expense of drums, which are heavy enough that, when they have been installed on the wheels, the entire assembly may be mounted in the machine and the drums brought to a true surface.

It is useless to attempt to adjust brakes or make an exact test unless the brake mechanism is in proper operating condition. The car should be placed in position where the brake rigging can be carefully inspected. The use of a free-wheel car lift is quite an aid in this work.

Mechanical Systems. Test the brake pedal action and the spring return. Have the helper work the pedal while a careful inspection is made of each individual brake action. In similar manner check up on the brake linkage. Check the bushings or bearings. Check the toggle and cam action. Check the flexible shafts, clevis pins, equalizer action, stop screws, etc. If there is evidence of lack of oil, it is best to remove the clevis pins and disconnect the parts or apply penetrating oil and work the parts until they are free. Next, clean the parts and apply lubricating oil or grease as the need may be, then proceed to reassemble and adjust.

Hydraulic System. See that the flexible hose connections are all in good repair. Check and lubricate all spring action. Inspect the main and wheel cylinders for leaks. Check up on the tube fittings. See that the supply tank has a proper quantity of brake fluid. See that the system has the proper amount of fluid in it. If it has been giving any trouble, bleed it to remove any air pockets.

Brake Leverage. After all the parts are working freely, the next step is to see that all levers or cams are set properly for positive action. A lever should never pass center more than a slight amount. It should start back of center and advance to center position. Usually this means a vertical or perpendicular position when brakes are fully applied.

Internal expanding brakes will free up as the drums heat, since they expand away from the lining and the pedal may need to be advanced instead of allowing it to give back. It is also true that if the pedal travel is just enough to hold the car when the drums are cold, it may not be sufficient to hold the car when the brake drums have heated and allowed the tension to come off the system. In other words, the pedal strikes the floor boards, but the drum has expanded beyond the limit of travel of the shoes and the brakes do not hold. It is necessary to always have reserve pedal travel for internal shoe systems.

Equalizers and Rods. In the mechanical type of brakes, always check the position of the equalizer ends. They should be "squared across" the chassis. See that the rods are so adjusted that the levers and equalizer are right. Fig. 16 shows the correct position for the equalizer when the brakes are in the "off" position and also when the brakes are applied.

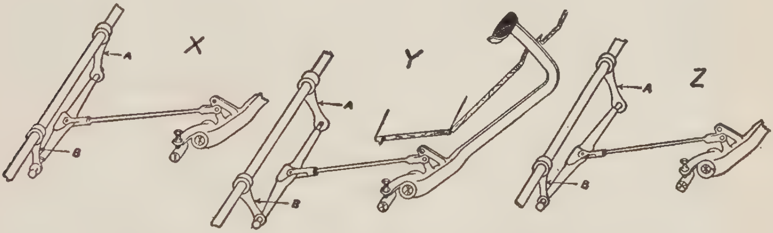


Fig. 16. *X*—Correct Position for an Equalizer When the Brakes Are in the "Off" Position
Y—Correct Position for the Equalizer When the Brakes Are Applied
Z—Faulty Action of the Equalizer Bar

Out-of-Round Brake Bands or Drums. Check up on the brake bands and drums for tight places. If the fault is in the band, have it rounded up. If it is in the drum, it will be necessary to remove the wheel and either replace or recondition the drum. Use a thickness gauge in this work to check clearance.

Adjusting the Brakes. It is not possible here to tell how to adjust the various brakes. The main point is to see that internal shoes are set as close as possible without any drag and that the brake action is right. With external contracting bands, see that they are provided with the proper clearance at the drum; then see that the levers are of equal and proper angle and that the equalizer, if such is used, is square across; and finally see that the rods are properly adjusted with reference to pedal travel.

TROUBLE SHOOTING CHART FOR BRAKE SERVICE

Brakes Squeak

Cause	Remedy
1. Exposed rivets	1. Reset or replace rivets
2. Loose or worn wheel bearing	2. Tighten or replace
3. Road grit or metal particles in lining	3. Remove with wire brush
4. Drum rust coating lining	4. Remove with wire brush
5. Frozen anchors, lever pins, and cams	5. Free parts and lubricate
6. Drums out of round	6. Remachine
7. Bands out of round	7. True up
8. Unequalized brake adjustment	8. Readjust brakes
9. Loose rear anchor stud	9. Tighten or replace

Brakes Chatter

Cause	Remedy
1. Lining loose on rivets	1. Reline
2. Drums out of round	2. Re-machine
3. Too much adjustment on pull rods	3. Release pull rods, adjust lining
4. Loose or worn wheel bearing	4. Tighten or replace
5. Loose axle spring seat	5. Tighten
6. Weak rear springs	6. Add extra leaves or heavier spring
7. Badly worn shoe or band supporter anchor pin	7. Replace worn parts

Brakes Grab

1. Equalizer frozen or off center	1. Free and secure proper equalization
2. Lining coated with grease	2. Reline
3. Sticky brake linings	3. Reline
4. Too much adjustment on pull rods	4. Release pull rods and adjust lining
5. Loose or worn wheel bearing	5. Tighten or replace

Brakes Drag

1. Broken or weak pull back springs	1. Replace
2. Frozen linkage units	2. Free and lubricate
3. Interference of linkage units or pedal	3. Clear parts
4. Release springs in improper position	4. Re-locate

Brakes Not Holding

1. Grease on lining from leaking wheel	1. Clean and replace felt in lining
2. Over-lubricated parts	2. Clean and do not over-lubricate
3. Rusty hand linkage and pull rod ends	3. Clean and lubricate
4. Road grit or metal parts in lining	4. Clean with wire brush
5. Too much adjustment on pull rods	5. Slacken pull rods, adjust lining
6. Drums scored or out of round	6. Re-machine
7. Exposed rivets contacting drum	7. Reset or replace rivets
8. Lever position incorrect	8. Release pull rods and adjust lining
9. Drum rust on lining	9. Remove with wire brush
10. Lining worn	10. Reline
11. Lining coated with grease	11. Reline

One Brake Will Not Hold

1. Lining coated with grease	1. Reline
2. Lining worn	2. Reline
3. Bent brake parts interfering	3. Straighten and line up correctly
4. Frozen pull rods and levers	4. Free and lubricate
5. Too much adjustment on one rod	5. Slacken off on rod
6. Weak release spring	6. Replace or tighten

Lining Wears Rapidly

1. Dragging brakes	1. Clean, free, and lubricate
2. Drums scored or out of round	2. Re-machine

Lining Glazed

1. Coated with rust	1. Remove with brush or reline
2. Coated with grease	2. Remove or reline
3. Coated with road dust or metal particles	3. Remove with wire brush

MOTOR VEHICLE BRAKE PERFORMANCE

Grading Table from an Initial Speed of 20 Miles per Hour

Comment	Stopping Distance
Commercially perfect for 4-wheel brakes	Between 15 ft. and 18 ft.
Excellent for 4-wheel brakes	Between 16 ft. and 18 ft.
Good for 4-wheel brakes	Between 18 ft. and 20 ft.
Fair for 4-wheel brakes	Between 20 ft. and 25 ft.
Poor for 4-wheel brakes	Between 25 ft. and 30 ft.
It's no longer a 4-wheel brake car	Over 30 ft.

Comment	Stopping Distance
Commercially perfect for 2-wheel brakes	Between 30 ft. and 32 ft.
Excellent for 2-wheel brakes	Between 32 ft. and 35 ft.
Good for 2-wheel brakes	Between 35 ft. and 40 ft.
Fair for 2-wheel brakes	Between 40 ft. and 45 ft.
Poor brakes, need attention	Between 45 ft. and 50 ft.
Vehicle unsafe on highways	Over 50 ft.

BRAKE-TESTING AND BRAKE-TESTING EQUIPMENT

Sometimes the men in the shop shy away from anything which savors of a "scientific treatment." As a matter of fact, most service men are scientists. They figure things in a "common sense" manner. They reason from cause to effect. They understand levers, hydraulics, vacuum, gearing, and a vast number of scientific terms. Friction is no new playfellow. It is used, considered, and taken advantage of daily by the scientific service men in every city and hamlet.

It is good psychology to sell the customer on the fact that you have special equipment which will "prove" beyond all doubt the condition of each and every one of the four-wheel brakes, in relation to each other one. The fact that we have "gotten by" with the road test in the past is admitted. But the public is becoming "brake-test minded."

What Brake-Testing Equipment Should Show and Do. Brake-testing equipment should show that all brakes are equalized or balanced according to the design.

It should detect out-of-round drums.

It should duplicate road conditions in so far as possible.

It should show results in such fashion that the car owner is "sold" on needed repairs.

It should show the need of relining, adjusting, removal of grease, and other repair operations, if the brakes are in poor condition.

It should show the proper adjustment of properly serviced brake equipment.

It should save time for customer and shop.

It should improve the quality of work.

It should prove the balance between front-end and rear-end brakes, where a difference is specified.

It should save labor and misdirected effort.

It should develop confidence in ability to "whip" the toughest brake job.

It should enable the workman to detect leaking wheel cylinders and master cylinders in hydraulic brakes.

It should make possible the detection of the weak cross rod or shaft, the one which twists too much under pedal pressure.

It should eliminate the danger to car, passenger, and traffic generally of the side-skidding car, caused from unequalized brakes.

It should be so accurate that the workman can know the stopping characteristics of the car without a street or road test.

It should make it possible to eliminate causes of rapid brake deterioration, such as is caused by bad drums, unequalized brakes, and improperly operating brake rigging.

It should prove itself an economic necessity and a profit builder.

Types of Equipment. The simplest type of equipment is the lever, which is so designed as to test one wheel at a time and record the result on a graduated scale. Perhaps the most complex is the type which drives each of the four wheels at the same time and measures the result of the application of pedal pressure on gauges. Between these ranges of equipment are others, which vary in cost and ability to handle the job. From time to time new and improved equipment is introduced.

To make a brake test, power is turned on, which causes the motor to rotate the drum on which the tire rests. As it is turned against the brakes, held set by the pedal jack, Fig. 17, the pressure developed within the hydraulic cylinder is registered on the dial.

The principle on which the tester works is illustrated in Fig. 18. Power from the motor is transmitted through the floating worm gear and the worm wheel, which is mounted on the same shaft as the ribbed cylinder on which the tire rides. The resistance set up by the brake causes the floating shaft to move endwise and register pressure on the fluid (through arm and plunger), which is recorded on the dial gauge.

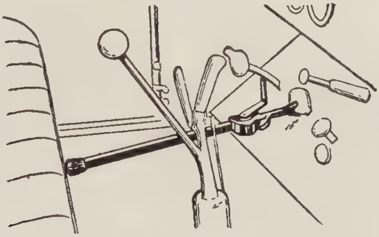


Fig. 17. A Brake Pedal Jack Is Used in Connection with Many Testing Devices for Equalizing Brakes

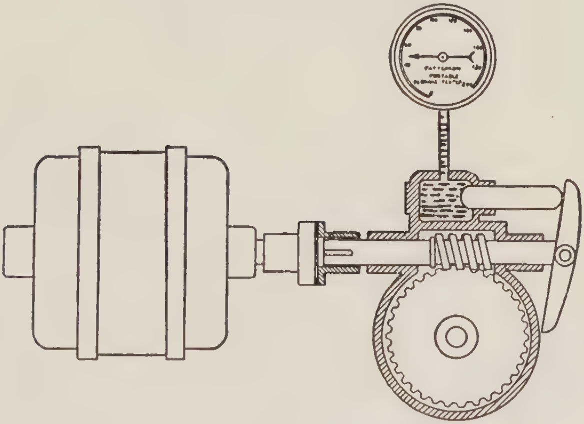


Fig. 18. The Principle of the Brake Testing Equipment

When making tests with the Jumbo tester, the pedal pressure normally used to stop the cars from 30 to 50 miles per hour is used.

As shown in Fig. 19, the device is so designed that when braking pressures are applied, the roller assemblies rock forward. This results in the hydraulic pressure plunger being forced into the hydraulic cylinder and then registering the force of this forward movement on the oil within the cylinder. The amount of pressure in any cylinder of the four is registered on the gauges, two of which are at the front of the machine and two at the rear.

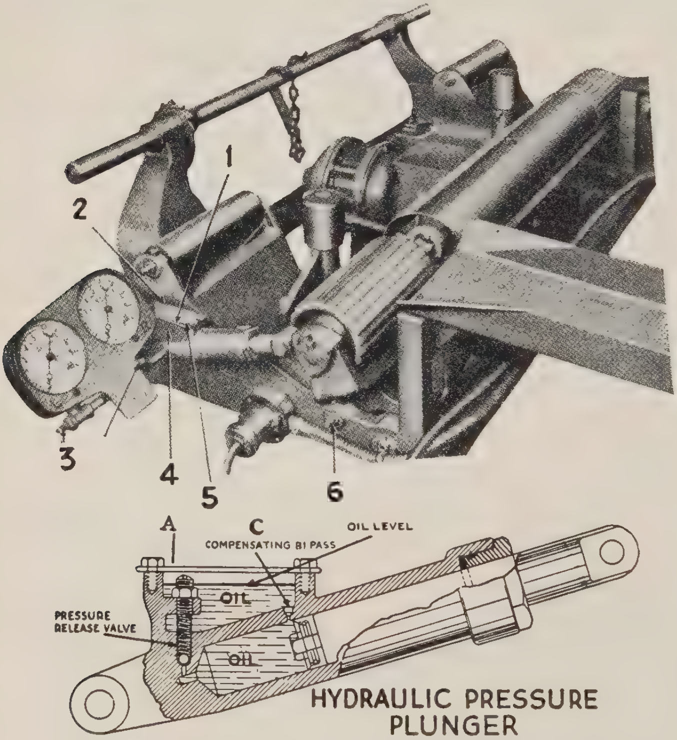


Fig. 19. The Principle of the Jumbo Testing Equipment
1—Pressure Release Valves. 2—Reservoir Oil Cap. 3—Covered Fittings.
4—Oil Reservoir. 5—Compensating By-Pass. 6—Whole Roller Assembly Rocks Forward on This Shaft.

Another four-wheel testing outfit is the Cowdrey dynamic brake tester. This is also motor driven. The general design of the equipment, which is available in a variety of forms, for either two-wheel or four-wheel installation, is shown in Fig. 20. The tire of the car rests on the driving rolls *A* and *B*. The wheel is turned against the resistance of the brake as these rolls are driven by the electric motor *C* through the worm and gear *E* and the planetary action *F*. The weighing or recording mechanism is shown at *D*. The "pull of the road" is indicated on an accurate weighing scale. The reading is obtained by means of the planetary action of the train of gears. The amount of this action is directly proportional to the brake action.

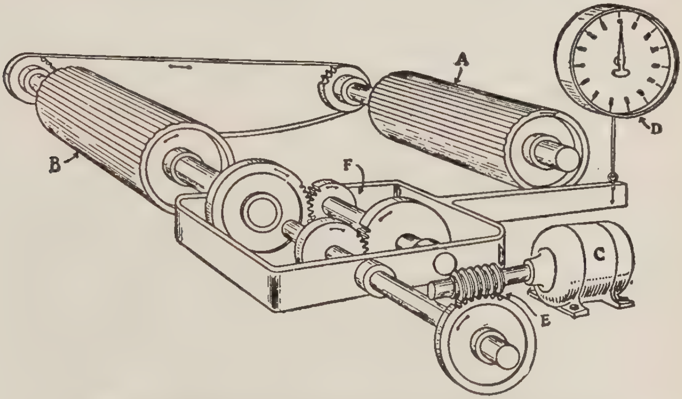


Fig. 20. The Principle of the Firestone-Cowdrey Testing Equipment

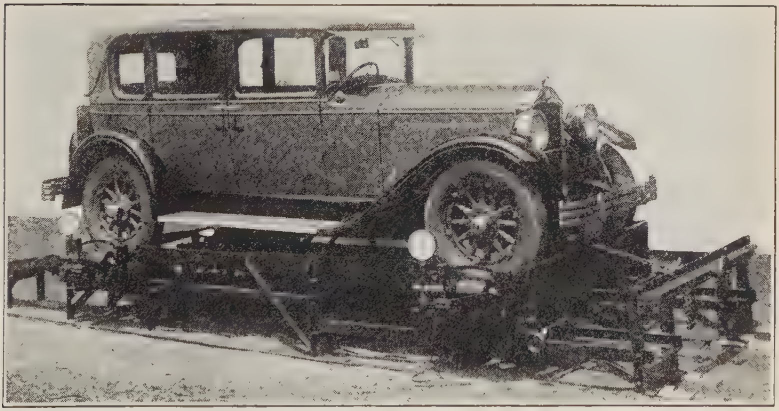


Fig. **21.** A Car Ready for Test on the Firestone-Cowdrey Tester

One recording gauge is provided for each wheel. A pedal jack is used to hold the pressure evenly on the brakes and the equalization and balance can be read quickly. By adjusting the brakes, exact equalization between wheels is possible and balance between front and rear. During the testing operation, the car is held from climbing the rolls by means of a chain.

The Cowdrey equipment is made in a great variety of sizes and capacities. Certain units, Fig. 21, are designed especially for the small service station, others for the large passenger-car service station, others for the truck and bus maintenance station, and still others for the factories; the latter usually being pit installations.

The Weaver four-wheel brake tester, Fig. 22, works to register the relative braking efficiency of the four-wheel brakes when the car is driven over it at a medium speed and then just as the front wheels pass onto the front platform, the driver sets the brakes. Four columns of liquid are used to register the relative braking effect. These may be noted within the glass cylinder on the brake-machine pedestal. This particular machine is designed to be placed in a driveway into a garage or service station so that the driver of the car as he enters may test the brakes. The results of the test are read direct from the driver's seat or by the service man on the outside.

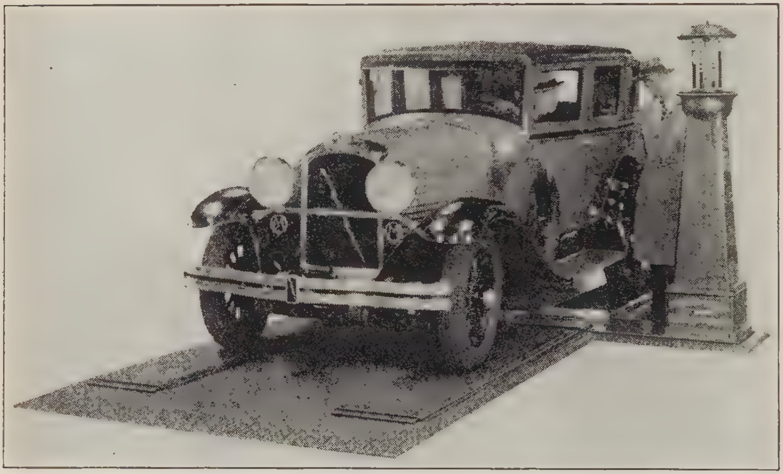


Fig. 22. Weaver Automatic Four-Wheel Brake Tester

As long as the car is on the machine, the brake reading remains visible. When the car is driven from the tester, the liquid in the tubes returns to the level so that another machine coming in may use the device at once. The machine is designed as a silent salesman of brake adjustments and relining work.

BRAKE RELINING

One of the most profitable of services in the automotive field is that of the brake service station. It is also a branch of the service requiring a fund of information and ability to diagnose trouble. The external brake band usually carries a woven lining. This is comparatively easy to install. Most of the brake-lining business over a long period of years was built up on the installation of the woven lining on the internal expanding shoe and the external contracting band. On the two-wheel brakes almost any type of lining could be used and made to equalize and give service. At no other point of the brake servicing field has there been a greater change than in this one particular item.

Owing to the fact that many of the brakes are now operating upon the servo principles, the type of lining selected must be in accord with the design of the brake system. In many cases this means a moulded instead of a woven lining. The point to be held in mind here is the fact that not all brake linings have the same friction qualities. Since the brake drum tends to drag the servo shoes around with it, it will be seen that the friction coefficient of the lining will have a great deal to do with how effectively the primary or servo shoe is carried around. If a lining of improper friction qualities is applied, one of two things will result—either the servo action will be weak and the customer will complain about too much effort being required to set the brakes, or a severe action will be exerted which may result in the wheels of the car being locked and thus causing an accident. The existence of these rather essential conditions makes it necessary, when servicing a system of brakes of the servo principle, to take the old brake shoes off the car and return them to the brake service station maintained by the manufacturer of the brakes. They will be exchanged for shoes which have been relined and burnished and ready for installation.

On the other hand there are many jobs of brake servicing on which the job of relining may have to be done in the service station. These can be handled at a profit, depending on the type of equipment which is available. If but a few jobs are handled a month, it is not a good policy to invest in brake-lining machinery. The work can be done by hand in a very satisfactory manner. However, if a considerable quantity of brake servicing work is done, a relining machine will pay for itself.

Drill the lining and rivit one end to one end of the brake band. When drilling, use a countersink and drill combination. In Fig. 23 two methods for applying the lining to the band are shown. In the case of the improper method, the rivet head is not countersunk a proper depth. This results in a squeaking brake as the head of the rivet is in contact with the steel of the drum. In the proper method of counterboring, the head of the rivet is countersunk approximately one-half the thickness of the lining. Use care to see that the counterbore does not extend more than half-way through the lining. Otherwise the lining may be drawn away from the band or shoes when the brakes are applied.

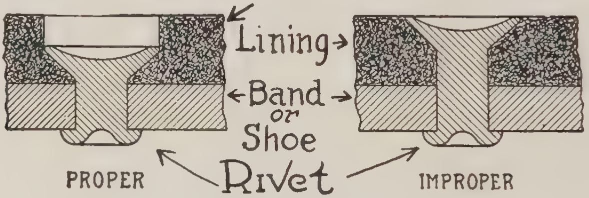


Fig. 23. Proper and Improper Method of Drilling and Setting Brake Rivets

When setting rivets by hand, the rivet is selected with considerable care so that it will be of proper length and diameter. Place the rivets through the lining and then use a square end punch or a piece of rounded steel with a cross section just as large as the rivet head. Hold this steel in the vise in such a manner that the work may be swung over the vise and the rivet head brought to rest on the end of the steel. Drive the band down around the rivet so as to force the rivet up through and in close contact with the lining, after which a few sharp blows with a hammer will properly set it. When riveting lining to the band or shoes by the hand method, solid rivets are used. These may be of brass, copper, or aluminum. Some manufacturers claim that the brass rivets are superior, because they are not so likely to cause squeaking of brakes when the heads gradually come in contact with the brakes after considerable wear has occurred.

Relining Brakes with a Power Machine. For the sake of "speeding up" brake relining and making the job of brake relining a profitable service operation, a number of special brake relining machines have been designed and placed on the market. Primarily, these machines consist of one unit for drilling and countersinking and another unit for setting the rivets. Some machines are provided with additional features, such as a device for cutting rivets when removing old lining. Fig. 24 shows a mechanic using a machine of this nature for a rivet chiseling operation. The brake band is held in position on the anvil, with the chisel *A* in the head of the machine. As the foot

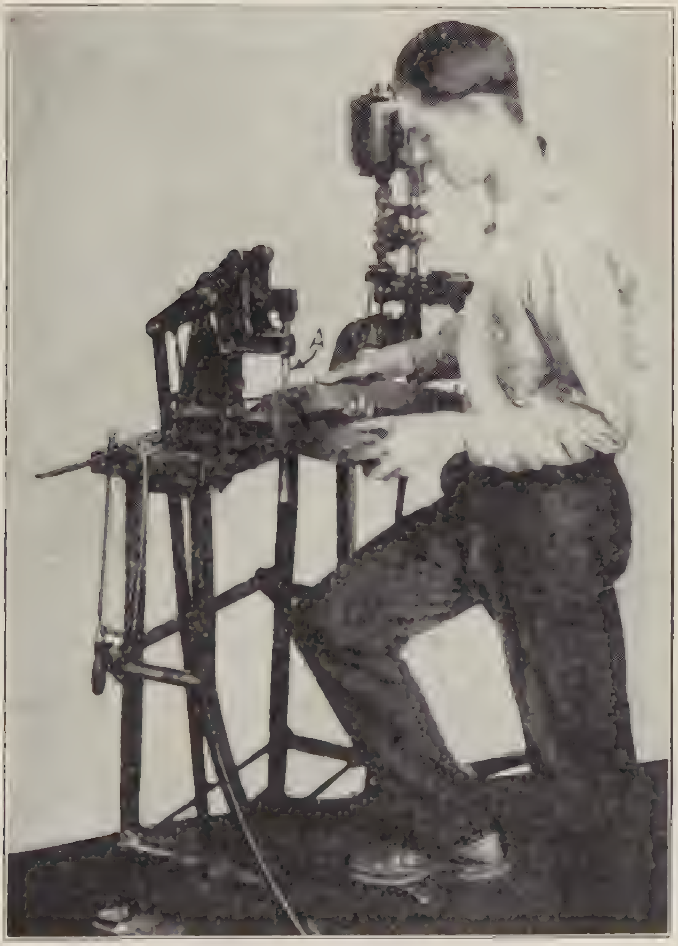


Fig. 24. Using a Brake-Lining Machine to Cut Off Rivet Burrs

pedal is forced downward, a considerable pressure is exerted on the chisel so that the brake-lining rivet burr is cut away.

When preparing a brake band for relining, the process is the same regardless of whether or not it is to be done by hand or by a brake relining machine. After the holes are drilled and counterbored for the rivets, the rivet attachment is used for setting the rivets. This is the same attachment as that which was used for chiseling off the rivet burr, but when doing riveting, other tools are installed.

Riveting Linings to Brake Shoes. The brake shoes are of a variety of forms, and earlier cars carried a shoe which was more or less flexible. In most of the internal-expansion four-wheel brake jobs, the shoes are die castings of aluminum or aluminum alloy, so that they are interchangeable one with another of like design.

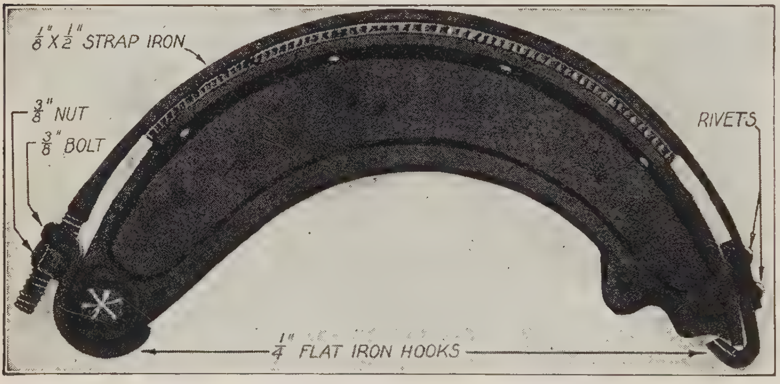


Fig. 25. A Clamping Device for Holding the Brake Lining to the Shoe While Riveting

When it is necessary to reline them in the local shop, all of the shoes should be relined with the same grade of lining, and this should be selected as near as possible according to the car or brake manufacturer's specifications. Applying this lining to the shoes is more difficult than applying the lining to the external band. The linings are usually applied in either two or three sections. These short sections are a little more difficult to handle and have them lie close to the shoes when the job is complete. In many instances it is necessary to have the linings applied by hand, since the nature of the shoe casting makes it very difficult to design a machine which will do universal work when relining shoes.

When relining internal brake shoes, the chief consideration is to see that the lining conforms to the shoes and that there are no bumps. It is useless to attempt to adjust a set of brakes if the shoes are not properly lined. The bump will give a dragging action to the brake, causing heating and other trouble. The amount of clearance allowed between the internal shoes and brake drum is so slight that trouble is certain to arise from an irregular lining job. The clamping device shown in Fig. 25, which may be made in the shop, will draw the lining tight and hold it while rivets are being set. The ½-inch strap iron is not in the way of setting the rivets and the device is left in position until all rivets are set.

Preventing Brake Squeaks. One method used to rid a set of brakes of undesirable noise is removing all the internal brake shoes and roughing up the internal surface of the brake-shoe lining. This may be done by means of a stiff wire brush, an old file, a wire brush buffer, or by grinding the surface very lightly.

A cause of noisy brakes is glaze, which frequently forms on the brake-lining surface. The brake drum surface may be highly polished. These two very hard surfaces do not prevent a proper friction-producing combination, except in severe pedal pressure, at which time noise or chatter may arise.

It has been found that if a fine cut file is used to scratch minute hair lines across the highly polished internal surface of the brake drum, these scratches act as teeth to cut off the glaze on the brake lining and to keep it from glazing further, so that the desirable "soft pedal" action with brakes free from noise is more readily secured.

RECONDITIONING BRAKE DRUMS

While in the old two-wheel brake systems an out-of-round or scored brake drum was considered something to be put up with, this situation does not exist with reference to four-wheel brakes. Customers expect and demand those things they have been sold by the new car dealer and factories through the advertising pages. A mechanic or brake service-station owner must recognize these facts and set up his shop with equipment which will give the type of service that car owners expect. The grade of lining and its method of application have much to do with the service the job will give. Not all of the fault is with linings; a part of it may well be laid to the drums.

Many car manufacturers machine the brake drums after they have been mounted on the wheel, so that the brake drum does offer not only a true surface but also a true turning surface to the action of the brake-shoe lining. On the other hand, production demands for low cost forces thousands of cars upon the road each year which are supplied with drums stamped from sheet metal and bolted in position on the hub without further machining or truing operations. While the high standard developed and held to with reference to stamping machinery gives a drum that is fairly accurate, it often happens that by the time it is mounted on the wheel slight irregularities creep in, and the job develops high and low spots, as is evidenced by the high and low points when an attempt is made to set up the drum in service.

A prime requisite when reconditioning brake drums is to have a brake-drum machine which will permit the wheel and drum to be swung as a unit. There are a number of these machines on the market especially designed to handle a wheel, even with the tire mounted. The question arises as to which gives a better job, a turned drum or one which has been ground. Some engineers contend that a "too smooth" surface is likely to set up squeaks or chattering and claim that a turned drum, having some lathe tool marks on it, will serve to break down the hard surface, which sometimes forms on brake lining, and keeps the lining in condition to give the much desired "soft pedal" action.

A prime consideration is to have a machine which will swing the wheel and drum assembly, as it is useless to recondition a drum when it is not bolted in position as it would be certain to be out-of-true when it was mounted on the wheel and the wheel mounted on the car.

BRAKE-DRUM LATHES

Bendix Brake-Drum Lathe. When truing the brake drum on the Bendix lathe, Fig. 26, the wheel assembly is first mounted on a special arbor which is equipped with adapters fitting snugly into the hub bearing races. The arbor and wheels with tires are then mounted between the vertical centers of the lathe, having the weight of the job resting on the headstock center. The wheel is turned by means of a lathe dog which is attached to the headstock face plate, the dog engaging between the spokes of the wheel or in the holes usually

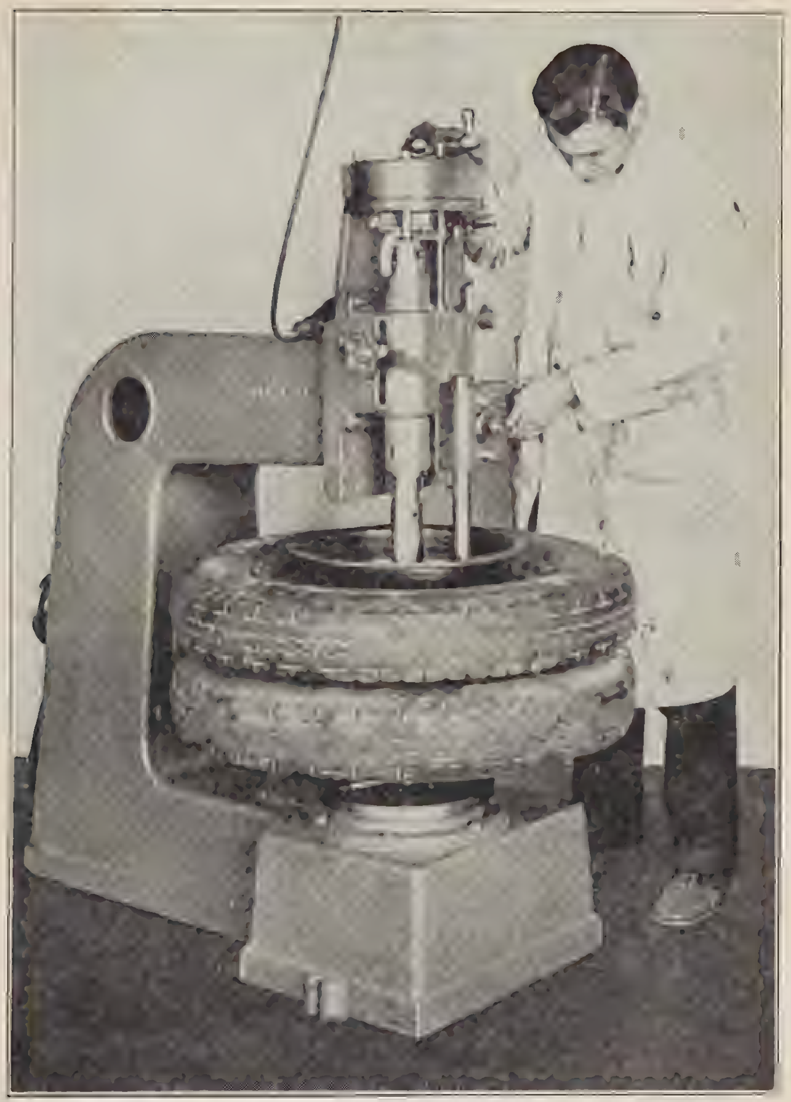


Fig. 26. Bendix Brake-Drum Lathe

found in disc wheels. After the tailstock center has been properly adjusted, it is tested for running.

The next step is to set up the cutting tool and test it against the drum to find out the approximate amount of material to be removed. Usually not more than two cuts are required, and only that amount of material is removed which is necessary to true up the out-of-round and scored drum. The machine is driven by means of an electric motor which is fully enclosed. The tool feed is controlled by means of a lead screw within the tailstock, just above the cutting tool. The cutting tool advancement is controlled by means of a screw. This machine may be equipped with a grinding head or attachment.

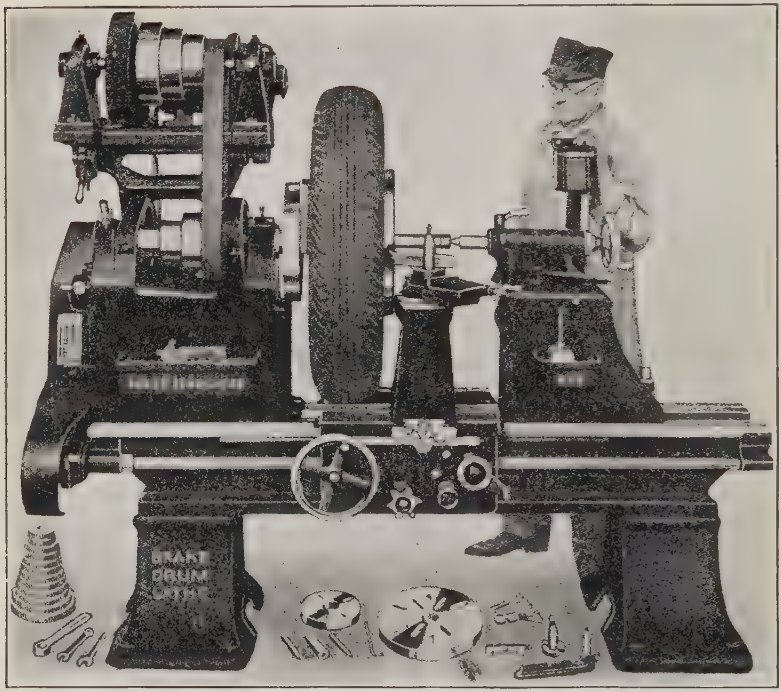


Fig. 27. South Bend Silent-Chain Motor-Driven Brake-Drum Lathe, with Wheel and Drum in Position for Turning

South Bend Brake-Drum Lathe. This machine is designed along the lines of the standard screw-cutting lathe. The main difference is the height of the headstock and the tailstock from the bed of the lathe, this distance being secured by the special design. Fig. 27 shows a 36-inch lathe with a passenger-car wheel and tire mounted between centers on a special self-centered mandrel, Fig. 28. The outer universal adapter *C* and the inner universal adapter *D* are automatically centered and align the wheel on the arbor when these adapters are forced together by the screw action of the arbor nut. After mounting the wheel and arbor assembly in the lathe, the job is driven by means of a special dog or face-plate driving tool.

Turning the Drum. The actual work of refacing or turning a drum is quite similar to any other lathe work. Speeds must be carefully figured so as to prevent the burning of the tool. If the tool is burned or wears rapidly, the quality of the work will suffer. High-grade tool steels are available and are usually used in the Armstrong type holder, Fig. 29, which illustrates the method of refinishing an internal brake drum by the turning process.

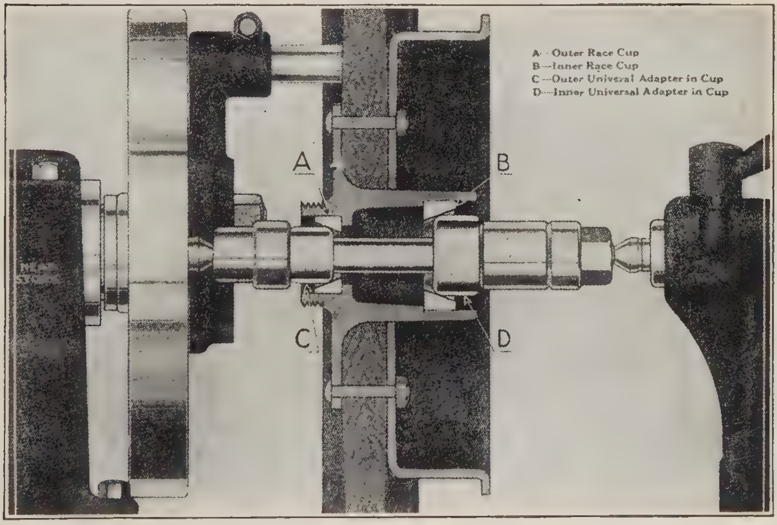

A—Outer Race Cup
B—Inner Race Cup
C—Outer Universal Adapter in Cup
D—Inner Universal Adapter in Cup
A
B
C
D

Fig. 28. South Bend Special Self-Centered Mandrel

Perhaps the greatest difficulty encountered in turning brake drums, aside from having tool bits not properly sharpened and maintained, is the tendency of the brake drum to chatter when the turning is under way. The usual method used to overcome this chatter is to attach a coil spring around the outer surface of the drum when turning the internal surface of the drum, Fig. 29. When truing an external surface, a special flat spring is sprung into the drum where it exerts the outward pressure, Fig. 30.

Some brake manufacturers recommend the use of rings to fit inside or over the drums, these rings being supplied with six or eight set screws so that the screw point may be brought into contact with the brake-drum metal and prevent this chatter. When these rings are used and properly applied, they will help to prevent the distortion of the brake drum under the pressure of the turning tool. On the other hand, careless operation of them may result in distortion of the brake drum and when the ring is removed after the job has been turned, the drum will spring back to its original form and be found to be out-of-round.

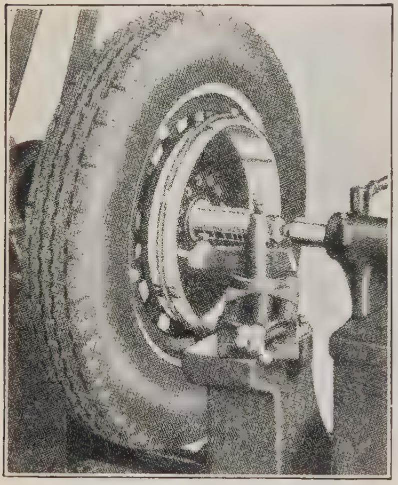


Fig. 29. Truing an Internal Brake Drum Mounted on a Straight Mandrel with Universal Bearing Adapters Mounted between Centers on the Lathe—Drum Size 17 Inches

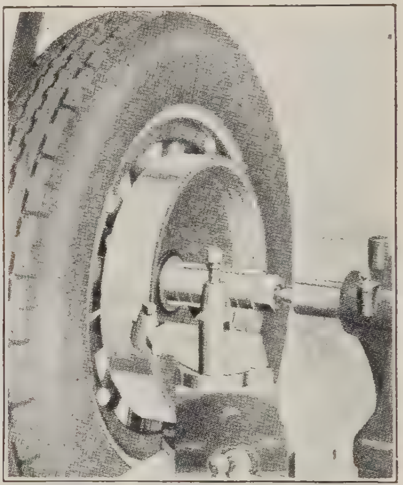


Fig. 30. Truing an External Brake Drum Mounted on a Straight Mandrel with Universal Bearing Adapters between Centers

Uses for Brake Lathes. There are a great many jobs around the average garage which may be performed by a lathe. These range all the way from small work, such as commutator turning on the generator armature to differential case truing, flywheel ring-gear replacement, wheel-hub flange truing, balancing wheels with tires assembled, and so on. With this very wide range of probable jobs, the owner of a general garage will need to give thought to the ability of the machine selected to cover the range of work. If the machine is being purchased for a special shop, such as do brake work only, the more highly specialized machines will no doubt make the greatest appeal both from the point of cost and economy of floor space and operation. If the shop work is more general, the machine which more nearly approaches the standard type of screw-cutting lathe would be more serviceable.

B.K. VACUUM POWER BRAKES

The vacuum power brakes are used very extensively for setting the brake shoes on heavy trailers and semi-trailers, as well as on trucks and buses. The application of the vacuum brake to passenger cars is illustrated in the case of the B.K. power unit, Fig. 31, in connection with several of the popular models described below.

1933 Studebaker Power Brake Unit Operation. (All Models). The power unit, Fig. 32, which assists the driver to operate the Bendix power duo brakes, consists of the following elements—valve operating lever *A*, power unit lever *B*, bell crank lever *C*, and vacuum power unit *D*, the front end of which is connected to the frame bracket and the rear end to the lever *B*. The vacuum in the power unit, supplied by a ½-inch line running to the intake manifold, is present at all times after the motor is started.

When the brake pedal is depressed, the initial travel operates the internal valve *E* within the power unit *D*. Atmosphere is admitted through the port *F*, first passing through the air filter *G* and the port *H* to the rear chamber of the cylinder *J*. Atmospheric pressure forces the piston *K* forward, actuating the power unit lever *B*, which in turn relays the power through the bell crank lever *C*, to the main pedal rod *L*, connected with the cross-shaft *M*. However, due to the fact that the power unit lever *B* has a clearance around the pedal shaft *O* and is pivoted at the pin *1*, a certain proportion of the power derived from the cylinder is balanced against the brake pedal *P*, through the pin *2*.

Although the braking force is obtained from the power unit, the "feel" of the brake pedal is in exact proportion to the deceleration desired by the driver.

A study of the three positions shown in Fig. 31 will explain the manner in which the manual and power forces are combined. With all parts in normal brake release position, the valve is held in the release or open position by valve operating lever *A*, Fig. 32, and a state of vacuum exists on both sides of the piston. It will be noted that the valve rod yoke is attached to the valve lever without clearance, so that any movement of the pedal is directly transmitted to the valve.

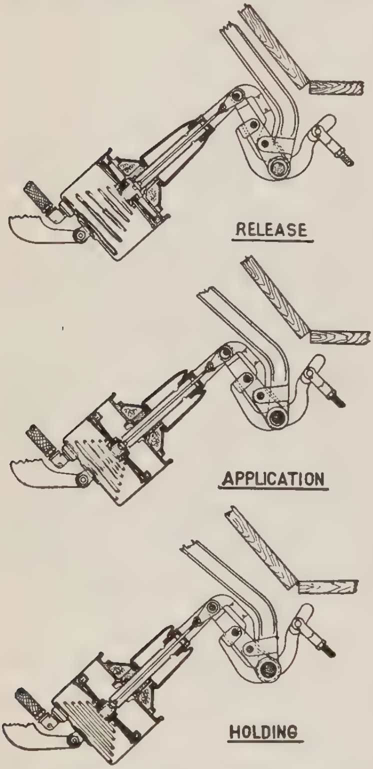


Fig. 31. Operation of a Typical B.K. Power Brake Application

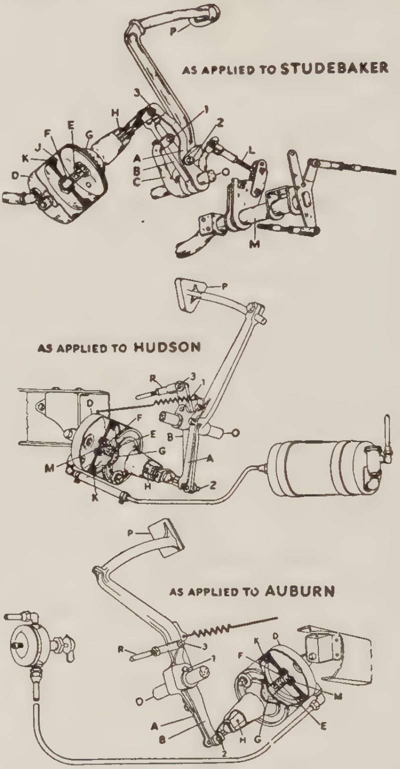


Fig. 32. B.K. Power Brake

The valve rod yoke, however, has an oversize hole, to provide clearance about the piston rod clevis pin *3* and permits operation of the valve without disturbing the relative position of the piston.

As the brake pedal is depressed, the initial movement actuates the valve, through the lost motion provided about the piston rod pin.

The valve is now drawn to the closed or application position, as shown in Fig. 31. Atmospheric pressure, through the air cleaner, hollow piston rod, and port beneath the valve, is admitted to the space behind the piston, partially destroying the vacuum. Vacuum is still maintained on the head side of the piston, so that it is driven forward by the atmospheric pressure.

The force of the piston is now exerted on the power unit lever *B*, Fig. 32, through the piston rod clevis and pin. Since lever *B* has a clearance around the pedal shaft *O*, the force from the power cylinder is balanced against the pedal force about pin *1* as a fulcrum; and when the force from the power unit has built up to a point of balance with the pedal effort through pin *2*, the leverage system is held in the neutral or "holding" position shown in Fig. 31. In this position the combination of the pedal effort and the power unit force is transmitted to bell crank lever *C*, Fig. 32, through pin *1*, and from the opposite end of the bell crank lever to the brake system.

The valve lever, being pivoted to the power unit lever by pin *2*, has been rotated to a point where the valve is moved to neutral position (with equal clearance on each side of the piston rod pin *3*), with both sides of the piston completely sealed.

An increase in braking effect is brought about by a repetition of the above, any increase in pedal effort again moving the valve to application position, admitting additional atmospheric pressure until the balance is again reached. This same proportional balance between foot pedal and power unit effort is maintained throughout brake release, just as during application. The pressure on the foot pedal exactly measures the amount of cylinder power and the final braking effect for any application, so that the "feel" of the brake is always maintained.

The leverage system is so designed that the same braking effect is now accomplished with but one-third of the effort formerly required, and braking need no longer be considered as a necessary drudgery of motoring, even by women drivers. The driver quickly gains a new feeling of confidence in the control of the car under all conditions, and fatigue and mental strain from brake operation are a thing of the past, even on long trips or in heaviest city traffic.

Adjusting and Lubricating Bendix Power Brake Units. Ordinarily no adjustment of the power units is required. It may happen, however, that, owing to the removal of the unit for general car repairs, setting would be disturbed. When setting up for adjustment, the first step is to see that brakes and brake pedal are in fully released position. Next, check the power unit to see that it is in fully released position. The power unit lever clearance hole should contact the forward side of the brake pedal shaft, as a stop, and the piston rod pin should just bear on the forward side of the control valve rod yoke, thus allowing fullest control valve rod travel on brake application. To effect adjustments, turn the nut on the control valve rod.

Two ounces of Bendix vacuum cylinder oil are required twice yearly for lubrication. This is fed in through the ports in the piston rod. Remove the dust cover over the air cleaner, remove the curled hair and wash it in gasoline to remove accumulated dirt, after which replace the hair and cover. Check to see that the rubber piston guard is in good condition and in place in its recesses.

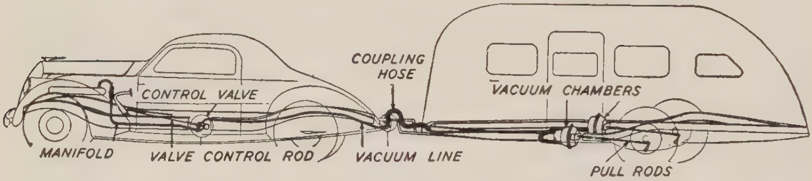


Fig. 33. Lathan-Besler Vacuum Power Trailer Coach Brakes
Courtesy of Lathan Company, Inc.
San Francisco and Detroit

VACUUM OPERATED TRAILER COACH BRAKES

In Fig. 33 is illustrated an automobile and trailer coach coupled together, showing the control valve, the vacuum line running to the manifold, the valve control rod, and the vacuum line running to the rear of the car. The arrow at the center of Fig. 33 indicates the coach to car coupling hose which is branched to run to the vacuum chambers. The pull rods as shown operate the brakes. The principle of operation insofar as the automobile is concerned is the same as though the braking system was controlling that unit; that is, the depression of the foot pedal opens the valve to vacuum which sets the brake shoes in the trailer wheels by means of the pull developed in the vacuum chambers or cylinders.

The simple plan of fitting the two-chamber installation for cable controlled brakes to the trailer frame is shown in Fig. 34. The mechanisms by which this action is accomplished are shown in detail in Fig. 35. The foot control valve *A* may be installed at any convenient point on the automobile frame and connected with a length of wire to the car brake mechanism. This is a compensating valve through which any degree of power desired can be applied and maintained on the trailer brakes simultaneous with, or in advance of, the towing car brakes.

A hand control valve is illustrated at *B*. This provides for independent control of the trailer brakes. It is a balance type valve allowing for metered or graduated brake control. Some operators prefer this type of brake. The illustration at *C* serves to show a simple form of hook-up for controlling both trailer brakes from one actuating chamber. The type of control shown in Fig. 34 is illustrated in detail at *D*, Fig. 35.

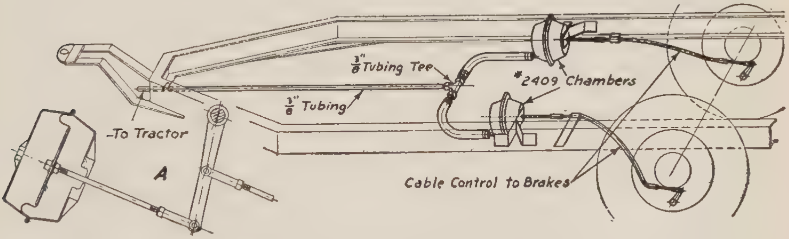
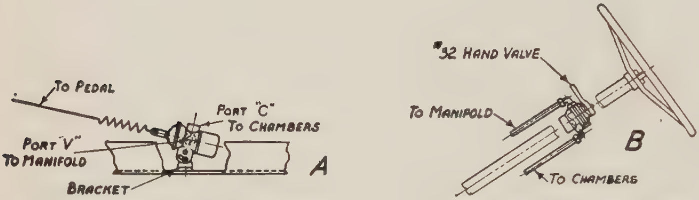


Fig. 34. Two-Chamber Installation for Cable or Rod Controlled Trailer Coach Brakes: *A*—Sectional View of Chamber

When the brakes on the trailer are hydraulic operated, the vacuum chamber may be hooked up as shown at *E*, Fig. 35, where it will be noted the cylinder is attached to the trailer frame and connected to a lever which is operated by the pull rod of the chamber. Lines of tubing running from this master cylinder operate the wheel cylinders.

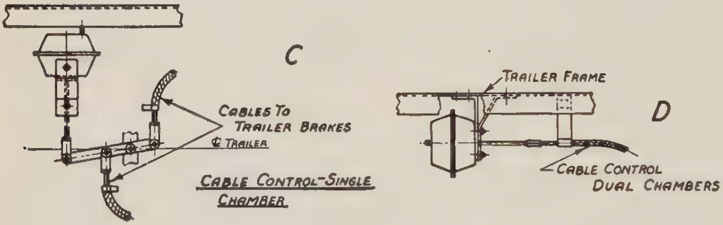
A method of hooking up rod or cable control brakes to a single chamber is shown at *F*. Note that an equalizer is incorporated.

When fitting the tow car, it is necessary to provide a shut-off valve, which is mounted in the rear of the car. In many cases, this shut-off valve is attached to the bumper brackets. The simple device illustrated at *G* necessitates the loosening of the hose clamp to remove the hose. A more convenient coupling assembly is shown at *H*. A dove tail coupling is fastened on the hose leading to the chamber.

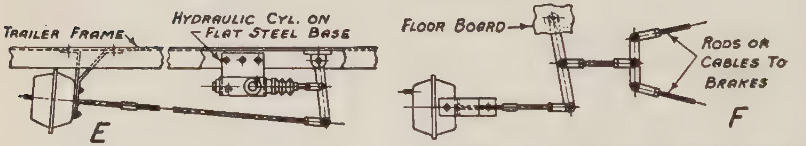


#39 Foot Valve Mounting on Frame

#32 Hand Valve Steering Post Mounting

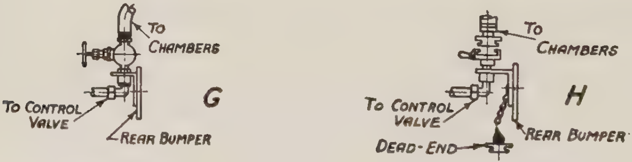


Cable Control-Single Chamber



Hydraulic Trailer Brakes

Rod or Cable Control - Single Chamber



Shut-off Valve

Coupling Ass'y.

Fig. 35. Lathan Trailer Coach Brake Fittings

A dead end dove tail is attached to the bracket by means of a short chain and is always available for closing the vacuum line when the trailer is disconnected.

When using the brakes of a house trailer, it is important that they be synchronized, one with the other, and desirable if they are synchronized with the action of the car brakes. If one trailer brake is tighter than the opposite, the coach will pull forward the loose brake, throwing the coach out of alignment with the tow car. It is sometimes desirable to have the trailer brakes operate in advance of the tow car brakes, this having a tendency to keep the two vehicles in line on a rapid stop and to prevent jack-knifing, which is the circumstance arising when the car stops faster than the trailer and the trailer swings forward around the car.

BENDIX=WESTINGHOUSE AUTOMOTIVE AIR BRAKE EQUIPMENT

The relative location of the various parts of the Bendix-Westinghouse automotive air brake system as used on coaches and long wheel base trucks is shown in Fig. 36. These parts and their functions are shown in Fig. 37 and are as follows:

An air compressor, driven directly from the engine crankshaft or from one of the auxiliary shafts, furnishes compressed air for brake operation. The compressor operates continuously while the engine is running, but the governor functions to unload the compressor discharge valves when 100 to 105 pounds reservoir pressure is reached, thereafter allowing the compressor to operate without any compression.

A suction strainer, filled with curled hair and connected to the intake port of the compressor, removes foreign matter from the air. Two reservoirs receive the air from the compressor and store it for use in the brake system. A governor regulates the reservoir pressure between minimum and maximum settings. A safety valve, located on the first reservoir, protects against the possibility of excessive pressure in the reservoirs.

A brake valve, operated by foot pressure, controls brake operation by directing the flow of air from reservoir to brake chambers in brake application and from brake chambers to atmosphere in release. A quick release valve assists the brake valve in release by exhausting the front brake chambers and thereby producing speedy and simultaneous release on all wheels. An air pressure gauge, located on the dash, indicates the air pressure in the reservoir. Brake chambers, one for each wheel, convert the stored energy of the compressed air into mechanical force to apply the brakes. A relay valve speeds up the application and release on rear wheel brakes.

Six wheel trucks have the same equipment with the addition of two brake chambers for the additional wheels; the relay valve in this case is located central to the four rear wheels to speed up their action in unison with front wheel brakes.

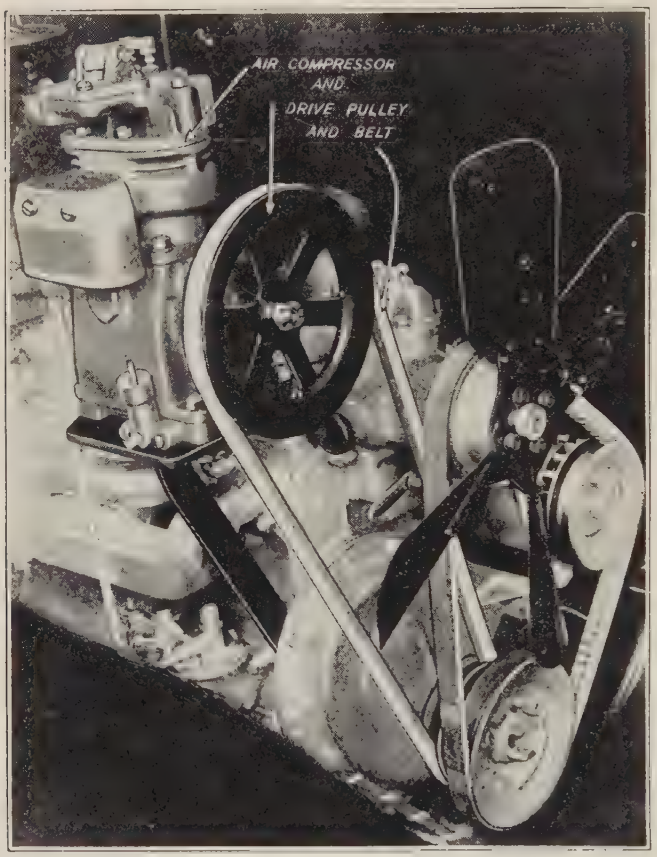


Fig. 36. Bendix-Westinghouse Air Compressor Mounted on Engine, Driven with V-Belt

Service Application. When it is desired to apply the brakes, foot pressure is applied to the brake pedal, which action is carried

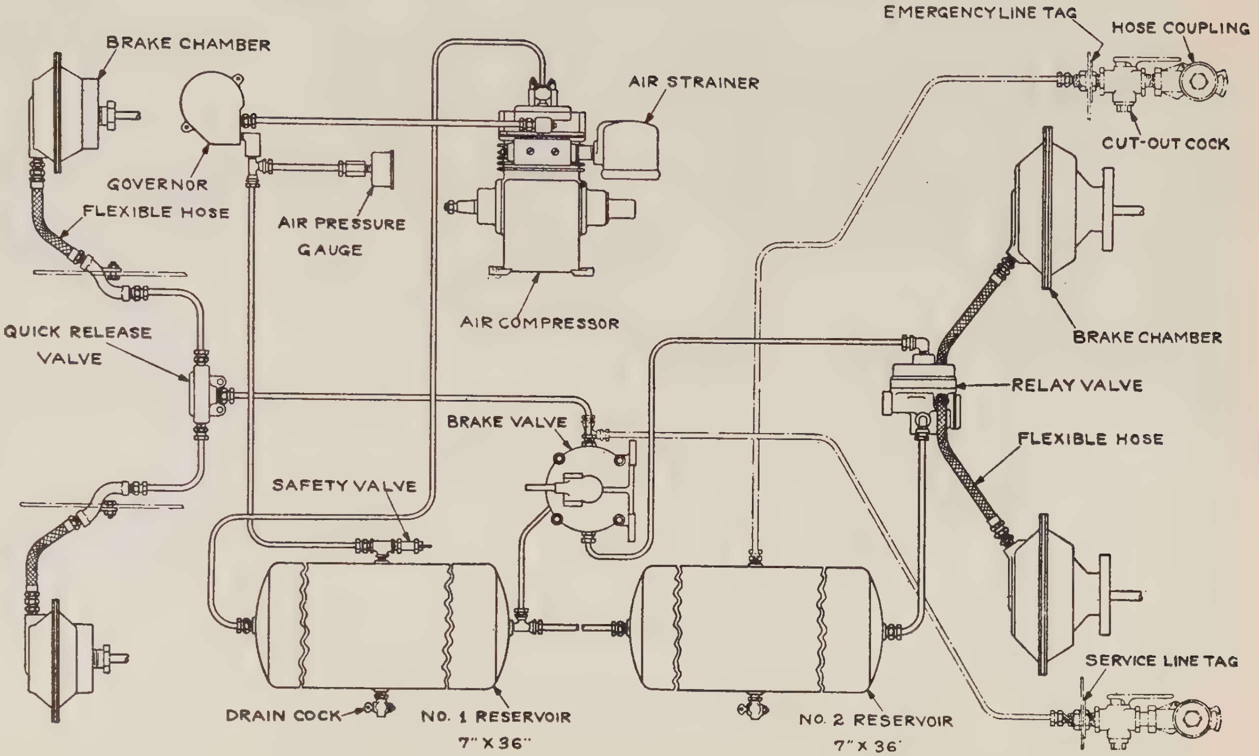


Fig. 37. Westinghouse Pressure Type Air Brake System for Buses and Trucks
Courtesy of Bendix-Westinghouse Automotive Air Brake Company

through the brake rod pulling up on the lever of the brake valve. Air is thereby admitted from the reservoir to the brake valve thence out the two side outlets to the front and rear brake chambers, respectively. The power thus exerted against the brake chamber diaphragms forces the push rods out, rotating the cam shafts to lift the cams and apply the brakes. In flowing to the front brake chambers, the air pressure passes through the quick release valve, entering at the top, deflecting the diaphragm and its seat to seal the exhaust opening while the air pressure passes around the diaphragm to the two side connections, each leading to a brake chamber. If a relay valve is used, the brake valve line passes to the top connection of this valve which then operates to pass reservoir pressure directly to the rear brake chambers.

Release. When the foot is removed from the brake pedal, the brake valve lever is moved back toward normal position again. This permits the exhaust valve to be unseated which opens the brake chamber line to atmosphere and allows air to exhaust from the brake chambers. If the brake valve lever is moved all the way back to normal position and left there (foot entirely removed from the brake pedal), the brakes will entirely release, but if moved only part way back (foot pressure eased), the brakes will only partially release. The brake chamber line to the front wheels is released only up to the quick release valve. Likewise, if the relay valve is used, it exhausts the rear brake chambers.

Operating Instructions. The foot pedal is normally held in release position by the action of a spring. To make a light application of the brakes, depress the pedal slightly; to make a heavier application, depress the pedal further. Removing the foot from the pedal automatically releases the brakes.

The air brake is designed so that when the lever of the brake valve is moved to the limit of its stroke an emergency application results, which will stop the vehicle in the shortest possible time. This heavy application should be reserved for emergencies, and not employed in ordinary service braking. The retarding effect depends upon the adhesion between the tires and the roadway, and is at a maximum when the wheels are just at the point of sliding. If the wheels slide, the retarding effect is, to a large extent, lost. The retarding effect of any given braking pressure is greater at low than at high speeds, and a heavy application at low speeds may result in sliding the wheels. When running at high speeds, however, a heavy initial application may be made, as it is desirable to obtain the most effective retardation when the speed of the car is greatest.

The best possible stop will be made when the brakes are applied as hard at the very start, as the speed, condition of the road, and comfort of the passengers will permit, and then graduated off as the speed is reduced, so that at the end of the stop but little pressure remains in the brake chambers. Never apply the brakes lightly at first, and increase the pressure as the speed diminishes—it not only makes a longer stop, but the final high pressure will likely be to produce a rough stop. In graduating the brakes off, do not "fan" the brake valve, repeatedly releasing and applying the brakes, as this wastes air pressure. Before starting the vehicle, observe the gauge. This shows the pressure stored in the reservoir, which must be 40 pounds or over, before the air brake can develop its full effectiveness.

WARNER ELECTRIC TRAILER BRAKE

The brake, Fig. 38, operates on current from the storage battery or electric system. One of the chief advantages from a trailer standpoint is that only one electric wire is needed as connection between the power car and the trailer. When the driver depresses the foot pedal (or moves the hand lever), a simple controller, Fig. 39, acting like a rheostat switch, sends electric current from the battery to an electromagnet in the brake. This magnet, circular in shape, can revolve in either direction within a limited arc. The current energizes the magnet and causes it to cling to an armature disc mounted inside the brake drum. The armature revolves with the drum and is kept in constant contact with the magnet by means of flat springs. The farther the foot pedal is depressed, the greater is the amount of current that reaches the magnet and the tighter the magnet clings to the armature. This attraction of the magnet to the armature causes the magnet to start turning with the armature. As the magnet turns, it engages a cam lever which in turn expands the brake band evenly against the brake drum in the conventional way.

The principle of the electric brake permits use of a self-adjusting feature to compensate for lining wear. As the brake band wears, the

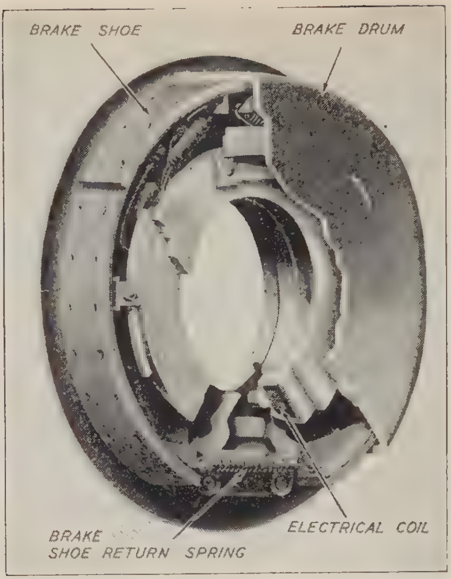


Fig. 38. Warner Electric Trailer Brake
Courtesy of Warner Electric Brake Manufacturing Company, Beloit, Wisconsin

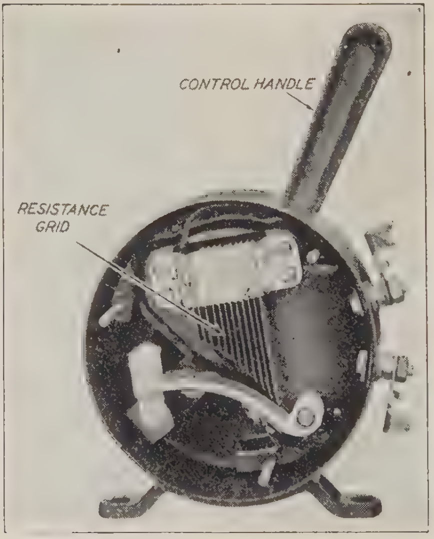


Fig. 39. Warner Electric Brake Controller Rheostat
Courtesy of Warner Electric Brake Manufacturing Company. Beloit, Wisconsin

electro-magnet moves a little further to drive the brake lining against the surface of the drum. An automatic stop on the brake band prevents the rivets from coming into contact with the drum under excessive wear, eliminating danger of scoring and assuring maximum life from the linings.

If the power car is standing still and the current turned on, there is no action of the brakes. Let the wheel revolve in the slightest degree, however, and the braking power is actuated. The magnetic clutch goes into action only when the wheels are revolving.

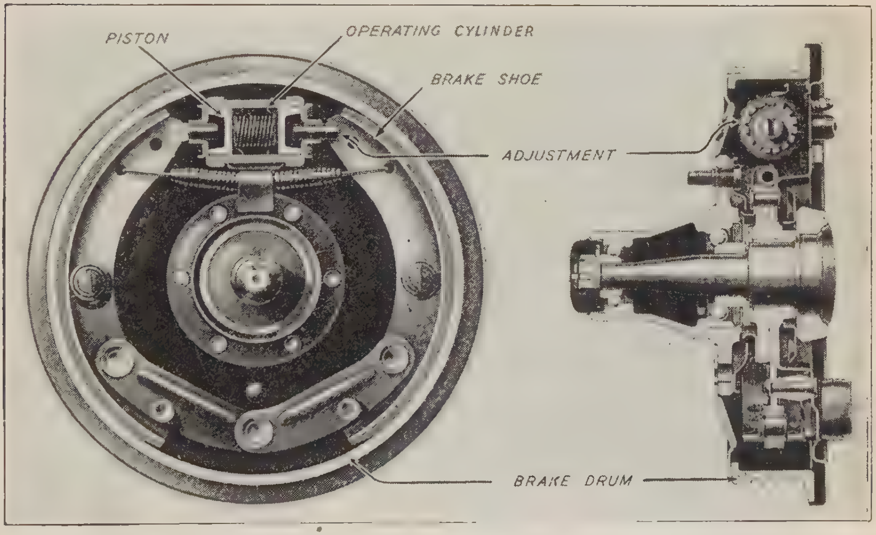


Fig. 40. Chevrolet Hydraulic Brake Front Wheel in Part Sectional View
Courtesy of Chevrolet Motor Company

CHEVROLET HYDRAULIC BRAKES

On the Master De Luxe Model, there is more car weight on the front wheels during the braking period than on the rear. For this reason, the proportions of 52½ to 47½ per cent were established by proportioning the sizes of the front and rear wheel cylinders in the same relation. At the same time, the cylinders were made large enough to prevent excessive pressure in the pipes and hoses. As a result, the front wheel cylinders are 1¼ inches in diameter, while the rear are 1$^{3}/_{16}$ inches. To provide the desired relation of the foot pressure at the brake pedal and the braking pressures at the above wheel cylinders, the main cylinder diameter was set at one inch. In each brake, two shoes, Fig. 40, hinging on double articulated links from a common pivot at the bottom of the brake, provide forward and reverse braking.

Brake Drum. The brake drums are of composite construction, each consisting of a cast-iron rim of heavy section, cast integral with a pressed steel web. The outer circumference of the drum, Fig. 40, is machined with four deep grooves to provide five parallel cooling ribs around the drum. The inside of the drum is machined after the wheel hub is assembled to assure absolute concentricity with its center and, therefore, perfect contact with the brake shoe linings. Both front and rear brake drums are mounted on the outside of the hub flanges. The front drum is permanently attached to its hub by three rivets, while the rear drum is held to the outer end of the axle

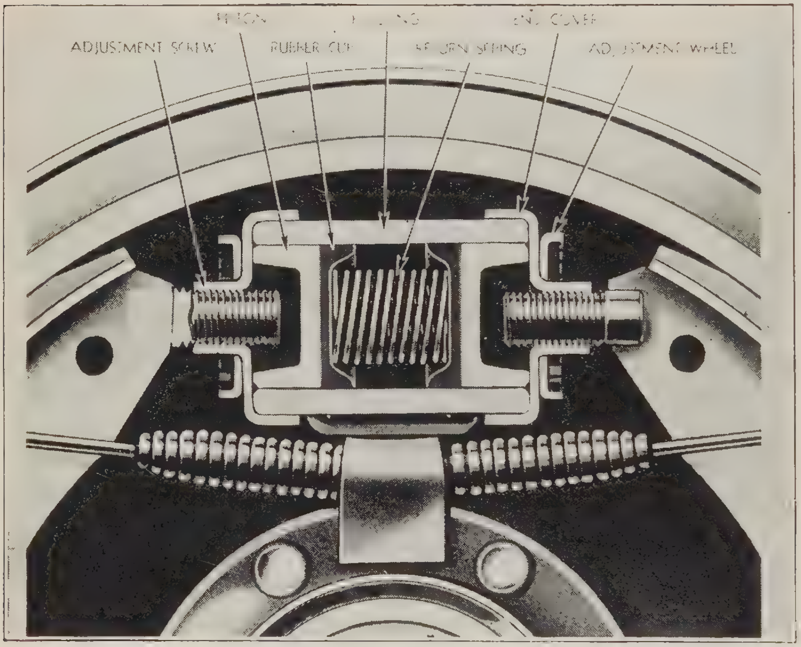


Fig. 41. Chevrolet Hydraulic Brake Wheel Cylinder
Courtesy of Chevrolet Motor Company

shaft by two screws. The wheel bolts are the major support of the drums, the attachments being provided only to retain the drums in place upon removal of the wheels. In either case, removal for servicing the brakes is simple. The wheels are first removed. The front drum is then removed with its hub and the rear drum removed by unscrewing the two screws.

Wheel Cylinders. In the wheel cylinders, Fig. 41, two sets of pistons, one for each brake shoe, are moved in opposite directions by hydraulic pressure to expand the shoes into the drum. Each set of pistons consists of a rubber cup, the piston proper, an end cover, and an adjustment screw, located in the order named from the cylinder center. The piston proper is an aluminum cup ground to a slip fit in the cylinder bore. The rubber cup at its inner end is moulded to fit tightly into the bore and acts as a seal to prevent the escape of brake fluid past the system. The end cover is stamped in two cup-shaped pieces, which are welded together back to back. These two pieces are called the "cover-proper" and the "brake adjustment wheel." The cover proper fits over the end of the cylinder housing on a machined pilot. It is fluted around its circumference, while the adjustment wheel, Fig. 42, has deep teeth formed in its flanged periphery. The adjustment screw extends to the brake shoe, a deep notch in its outer end permitting it to straddle the brake shoe web. At the center of the wheel cylinder, a light wire spring exerts pressure between the two sets of pistons, maintaining contact between their various component parts.

Main Cylinder. The main cylinder, Fig. 43, consists of a housing, piston, compensating valves and ports, and a combined piston and pedal stop. The housing is an iron casting incorporating a large reservoir for brake fluid and the cylinder in which the rest of the mechanism is contained. It is filled through a large hole at the top which is well sealed by a removable cap. Two drilled ports lead from this chamber to the cylinder. The large one is called a breather port and the small one a compensating port. The piston is a long, spool-like member with a rubber seal at one end and a rubber primary cup just ahead of the other end. This rubber cup is maintained in contact against the end of the piston by a light return spring. A combined outlet and return valve is held against its seat by the same spring. This valve is of rubber encased in a steel cage. Its seat is a rubber disc held in the end of the cylinder bore by a cap through which connection is made to the pipe line. The combined piston and pedal stop is a steel disc held in the opposite end of the cylinder by a ring lock. Movement of the pedal lever and push rod against the piston overcomes the return spring, permitting the piston and its cup to move toward the combined outlet and return valve. Hydraulic pressure through holes in the valve cage contracts the rubber valve and

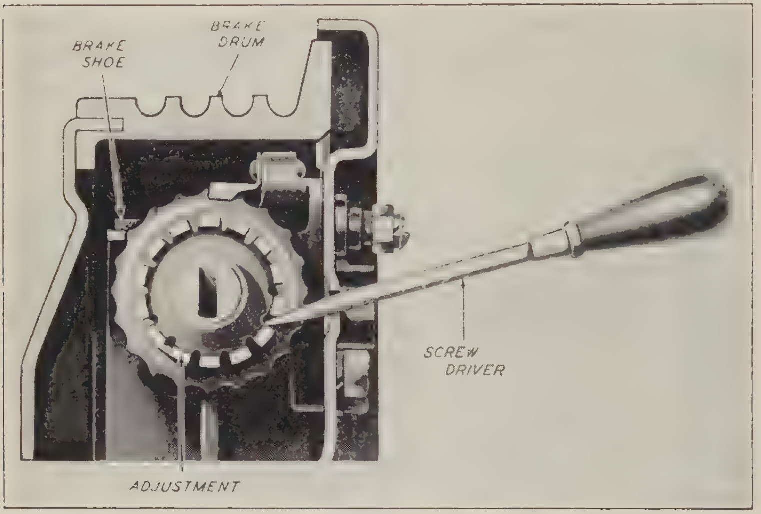


Fig. 42. Method of Adjusting Chevrolet Brake Shoes to the Drum
Courtesy of Chevrolet Motor Company

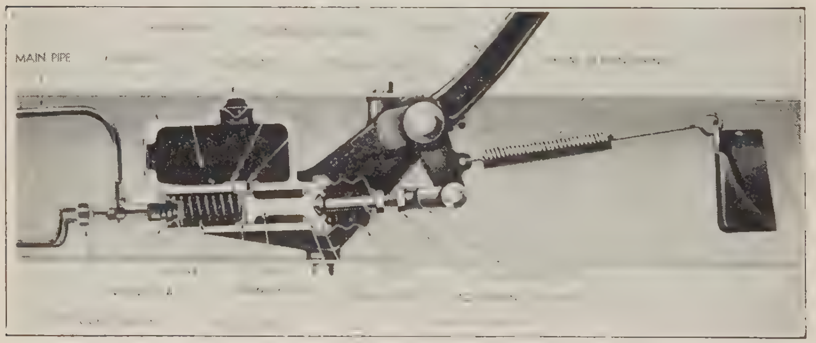


Fig. 43. Chevrolet Hydraulic Brakes Master Cylinder
Courtesy of Chevrolet Motor Company

the fluid in the cylinder passes through the cage to apply its force on the fluid in the lines. When the brake is released, the return spring forces the piston and its cup to return. The force of the retracting springs in the brakes overcomes the force of the return spring, pushing the valve away from its seat. The fluid from the lines flows around the valve back into the chamber. Then the valve closes, retaining a slight pressure in the pipe lines and wheel cylinders to prevent the possible entrance of air into the system.

The return of the piston and its primary cup to released position is faster than the return of the fluid through the lines into the main cylinder. Because of this, a momentary vacuum is created in the main cylinder. This draws additional fluid from the reservoir through the breather port, through drilled holes in the piston end and past the lip of the primary cup. Any excess is returned to the reservoir through the compensating port. Thus, a full cylinder of fluid is assured for every brake application.

Stop Lamp Switch. Because of the new hydraulic braking system, a stop lamp switch, as shown in Fig. 43, is operated by hydraulic pressure. It consists of two terminals moulded in a block of bakelite; a metal diaphragm which contacts the points of the terminals; a rubber disc which seals the diaphragm and contact points from the brake fluid; and, the housing in which these parts are encased. The housing is a large hexagonal bolt in the head of which is the chamber for these parts. After they are inserted, the end of the housing is spun over to resist the hydraulic pressure and to protect the contact points from dirt and corrosion.

The shaft of the housing is pipe-threaded externally and drilled internally. By this means, the unit is screwed into the same connector at the rear of the brake main cylinder from which the brake main pipe leads. When the brakes are applied, hydraulic pressure immediately overcomes the resistance of the diaphragm, which contacts the terminal points, causing instantaneous lighting of the stop lamp.

Hydraulic Brake Piping. All pipes are of steel tubing $\frac{1}{4}$ inch in diameter with walls $\frac{1}{32}$ inch thick. This tubing is formed of metal rolled (like a scroll) into a double wall thickness, with the ends of the rolled metal securely fastened together and sealed to prevent leaks. It is thoroughly plated on both outside and inside to prevent leaks and corrosion. Both ends of all pipes are flared at an angle of 45°, with lip of flare bent inward to form a double thickness.

Hand Brake. The hand brake operates mechanically on the service brake shoes of the rear wheels, Fig. 44. It is designed to provide twenty-five per cent more travel than that of the service brakes. The hand brake lever and its pull rod, Fig. 45, to the cross shaft are joined together through a pressed steel yoke, which straddles the lower end of the lever to which it is pinned. A heavy coil spring, Fig. 45, within the yoke bears against its bottom. The rod is adjusted far enough into the nut to provide a heavy load on the spring with the hand lever disengaged. Upon engagement, the hand lever is pulled back, exerting extra tension in the spring. This enables the pawl to engage teeth in the sector beyond the necessary travel of the linkage for brake engagement. As the shoes and drum cool, the tension keeps the brakes engaged. Within the brake, Fig. 44, a heavy

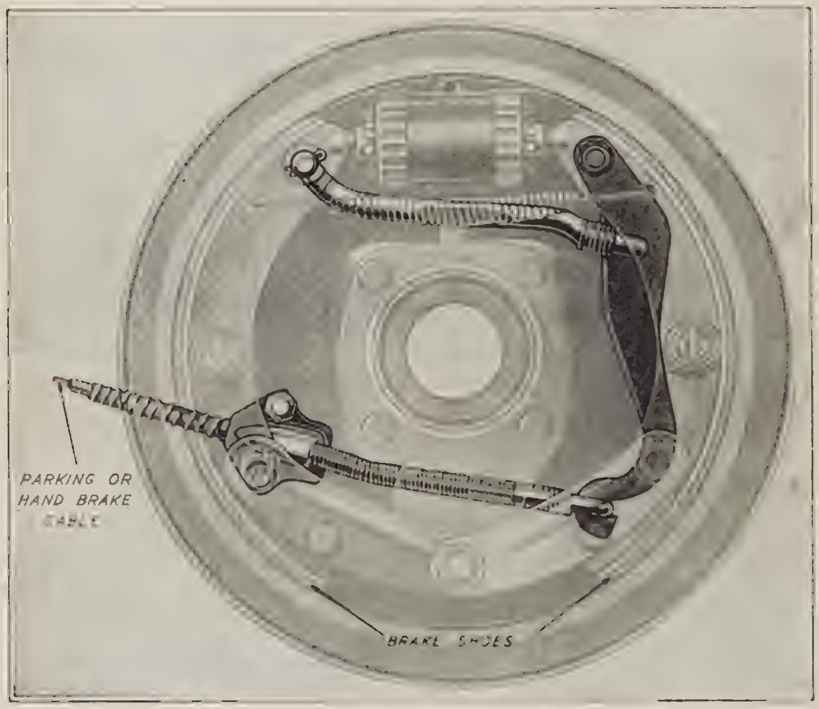


Fig. 44. Chevrolet Parking Brake Cable and Lever Control
Courtesy of Chevrolet Motor Company

stamped steel lever is pivoted at its upper end on a shoulder bolt in the web of the rear brake shoe, the connection permitting free movement of the lever. The lever lower end is stamped in the form of a hook, which engages an eye in a forged end attached to the cable.

When the hand brake is applied, the toggle action of this leverage forces the brake shoes into contact with the drum. A spring on cable bears against its anchor to brake flange plate and against its end eye to return lever to its normal position when brakes are released.

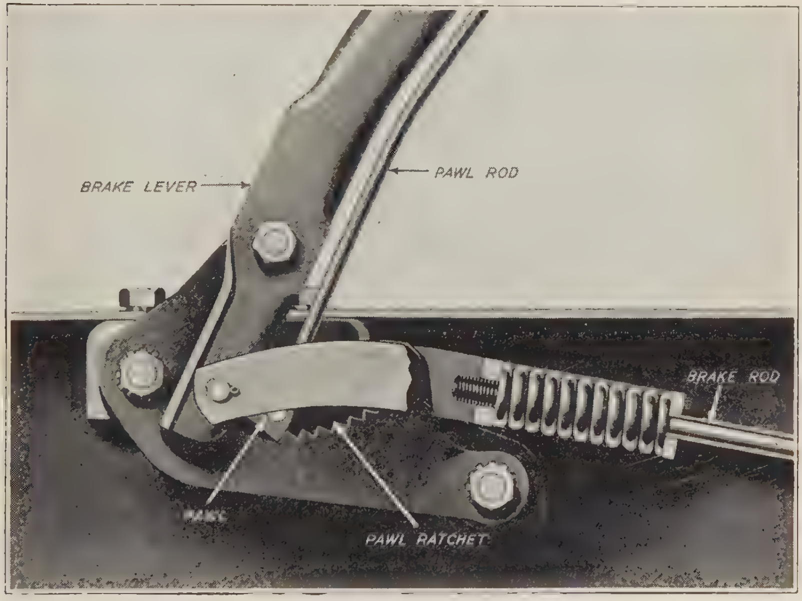


Fig. 45. Chevrolet Hand Brake Lever

SERVICING LOCKHEED HYDRAULIC BRAKES

The hydraulic four-wheel brake system in the case of the De Soto car is illustrated in Fig. 46. The master cylinder *A* is connected to a copper tube or line which runs to the rear a bit where it joins three feed lines, one of which feeds the two rear cylinders, and the other two marked *C* and *D*, feed the two front-wheel cylinders. The pressure induced when the foot pedal is forced downward, Fig. 47, causes the brake fluid to flow with equal pressure along the lines *B*, *C*, *D*, and the cross lines *E* and *F* at the rear, Fig. 46, with the result

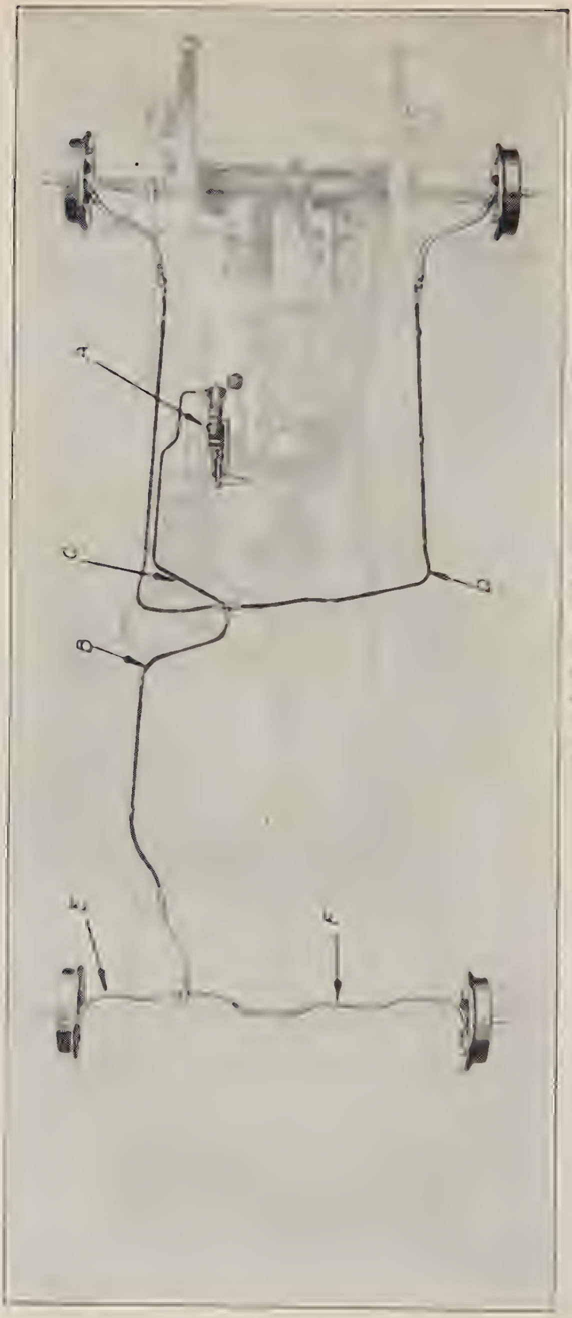


Fig. 46 Hydraulic Four-Wheel Brake System.

that the eight pistons within the four-wheel cylinders are forced outwardly with even pressure just as the four fingers of the glove were equally expanded.

The scientific principle with reference to equalized pressure on a confined liquid is illustrated in the case of the rubber glove shown in Fig. 48, where it is shown held close to the wheel cylinder of the Lockheed internal expanding brake system. When the hand holding the glove is squeezed shut on the liquid in the glove, equal pressure is induced in each of the fingers. The liquid does not compress, but the rubber glove stretches and the fingers grow larger due to the internal pressure, and the amount of pressure per square inch is equal for each and every square inch within the glove having any of the liquid under pressure in contact with it.

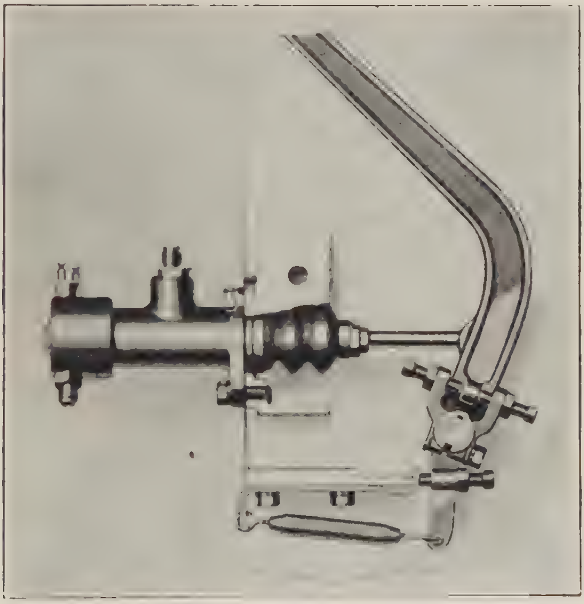


Fig. 47. DeSoto Brake Pedal and Master Cylinder Hook-Up

Now in the case of the hydraulic brake system, all of the tubes and cylinders are made of non-stretching fabrics or metals. The only parts which will give to make room for the liquid, which is sent from the master cylinder through the brake lines, are the pistons within the wheel cylinders. One of these is shown in section in Fig. 49.

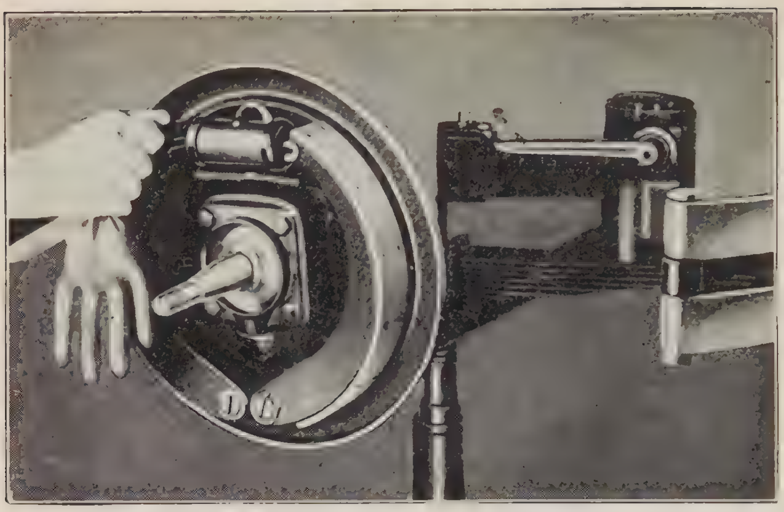


Fig. 48. Demonstrating the Hydraulic Principle on Dodge Car

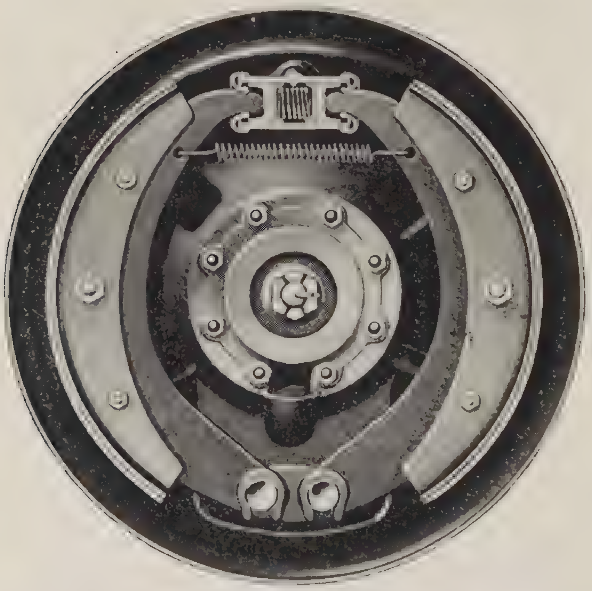


Fig. 49. Showing the Simple and Sturdy Brake-Shoe Construction Employed in the Hydraulic Four-Wheel Brakes of the Internal-Expanding Type on the Chrysler Imperial "80"

Just as the liquid under pressure flows to the fingers of the glove, so the brake fluid under pressure flows to each of the four brake cylinders and exerts exactly the same amount of pressure per square inch on each of the pistons. The hydraulic system may be said to be self-equalizing. Such inequalities as may exist in the braking system of any hydraulic brake equipped car would have to be due to the size of the wheel cylinders. Since, as a rule, these are all of the same size, the system is equalized.

It does sometimes happen that not all brakes are equally effective, but this is usually due to differences in the adjustment of the brake shoes, the quality of the lining, water or grease present on some of the linings, the drums being out-of-round, scored, or otherwise rendered unequal, return springs not equal, parts corroded or damaged so that they do not function properly, or other more or less mechanical faults that may have developed.

Now since each piston is in contact with the upper end of a brake-shoe rigging, it will be seen that the outward movement of the eight pistons move the eight brake shoes outwardly in a simultaneous fashion so that all eight of the brake shoe linings come into contact with the wheel brake drums at one time with equal force so that the braking effect, all other conditions being right, will be equally distributed to each of the four wheels and tires.

Lockheed Hydraulic Four=Wheel Brake System. The Lockheed system, Fig. 50, consists of a supply tank, a master cylinder, copper tubing, leading from the master cylinder to flexible hoses which connect the copper tubing to the brake cylinders. Simple in construction the brakes depend only upon the fundamental displacement principle of hydraulics for their operation and equalization.

The master cylinder is fitted with a piston, and the wheel cylinders are fitted each with opposed pistons; all of which are provided with cup packings of moulded composition rubber which act as a seal to maintain pressure and prevent loss of the brake fluid.

The brake pedal, when depressed, moves the piston within the master cylinder, thus displacing the brake fluid from the master cylinder through the copper tubing and flexible hose connections into the four wheel cylinders.

The brake fluid enters into each of the wheel cylinders between their opposed pistons, causing them to move outwardly against the brake shoes, thus moving them into contact with the brake drums. As pressure on the pedal is increased, greater hydraulic pressure is built up within the wheel cylinders, and consequently greater force is exerted against the ends of the shoes.

The very principle of hydraulics dictates that pressure exerted upon a fluid is transmitted equally to all surfaces. It is therefore obvious that the pressure applied at the foot pedal is equally distributed to each of the four-wheel cylinders, and that the pressure exerted against the brake shoes must also be equal.

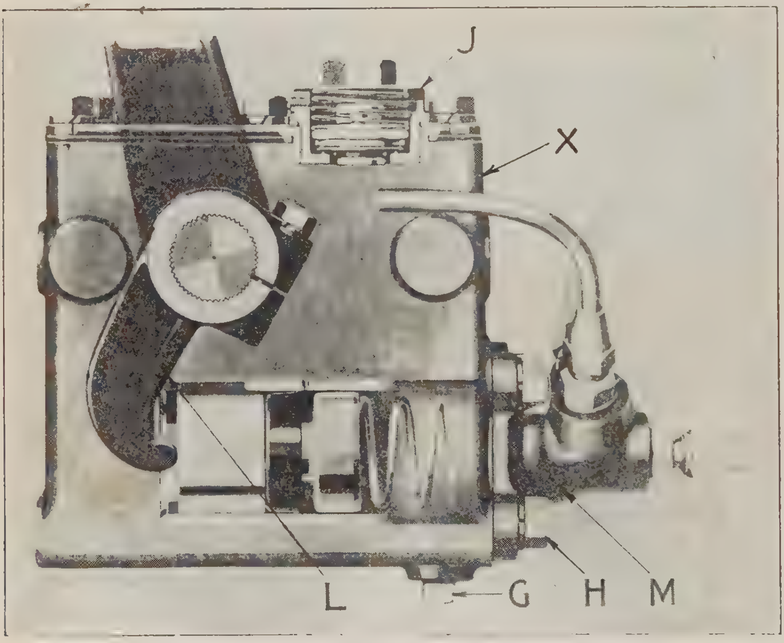


Fig. 50. Sectioned View of the Lockheed-Wagner Master-Cylinder Housing with the Supply Tank, Foot Pedal, and Brake Fluid Tubes

When pressure on the foot pedal is released, the return springs on the brake shoes retract and return the wheel cylinder pistons to their normal or "off" position, thus forcing the brake fluid back through the flexible hoses and copper tubing to the master cylinder.

Master Cylinder. The master cylinder, known as the compensator type, differs somewhat from the conventional type, being so designed that it automatically maintains a constant volume of fluid in the system; compensates for expansion or contraction of the fluid due to temperature changes; and replenishes any loss resulting from slight leaks.

The master cylinder *M*, Fig. 50, is contained within the supply tank *X*, upon which is mounted the clutch and brake foot pedals; the whole unit in turn is mounted directly to the car frame. This supply tank serves to carry the reserve supply of fluid. The master cylinder is submerged in the fluid, thereby protecting the system at this point from any danger of taking in air, dirt, or water.

Located so as to be directly forward of the master piston cup when the piston is in the "off" position is a port hole through the wall of the cylinder *B*, Fig. 51. A rise in temperature causes the fluid in the braking system to expand, the excess by-passing the port to the supply tank. A drop in temperature causes the fluid to contract. This loss is replenished from the supply tank through the port. Thus a constant volume of fluid is maintained in the system.

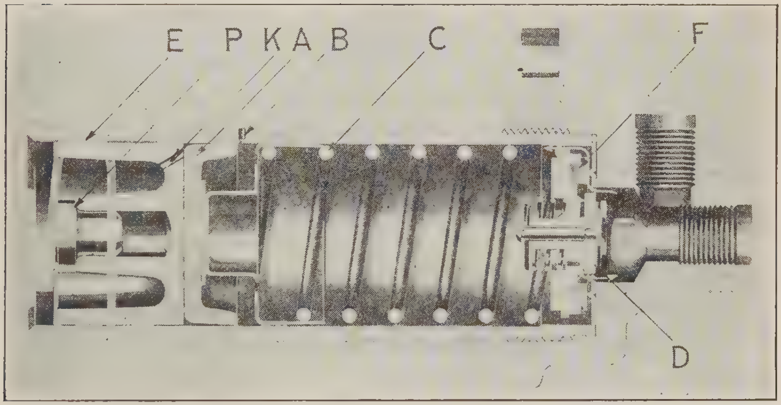


Fig. 51. Master Cylinder of the Lockheed-Wagner Hydraulic Braking System

From the foregoing it is apparent that the brake pedal must be set so that the master piston cup is back or clear of the port when the brakes are in the "off" position. The return of the master cylinder piston to its "off" position is accomplished by a return spring *C*, Fig. 51, enclosed within the master cylinder.

In the head of the master cylinder, held in place by a return spring, is a combination inlet and outlet check valve. When the brakes are applied, the master-cylinder piston is pushed forward, which opens the outlet check valve *D*. The fluid is forced through it into the system. When the brake foot pedal is released, the master-piston return spring forces the piston back to its "off" position against its stop. At the same time the wheel cylinder piston return springs are forcing the fluid back through the inlet check valve *F*, until the fluid pressure balances the weight of the master-cylinder return spring, when the inlet valve closes.

Should the return of fluid be insufficient to equal the displacement caused by the return of the master piston, a vacuum is created in the master cylinder sufficient to cause the master piston cup *A* to turn in at the lip and allow the fluid to by-pass from the supply tank in to the master cylinder. Any excess fluid by this means introduced into the system will pass freely into the supply tank through the port when the master cylinder piston returns to its "off" position. The combination valve functions differently when bleeding or filling the system with brake fluid.

Wheel Cylinder. The wheel cylinder, mounted rigidly to the dust shield, is fitted with opposed pistons, the stems of which are connected to the brake-shoe ends. The open ends are fitted with rubber boots to protect the cylinder from foreign substance. The fluid enters the cylinder between the opposed pistons. At the uppermost position and between the opposed pistons is the bleeder valve required for expelling the air when filling the system.

Supply Tank. The supply tank is a simple reservoir and functions to feed the fluid system. The filler plug *J*, Fig. 50, in the tank is fitted with a breather valve. When the system is inoperative, the breather valve seals the tank, preventing the evaporation of the alcohol content in the fluid.

Service Instructions. The supply tank should be inspected at least once a month and if the fluid level is found to be low, it is an indication of a leak at some point in the system.

No adjustment is required for equalization—the pressure delivered to the shoes will be the same at all wheels. Adjustment is only necessary to compensate for wear of the brake lining. The frequency of such adjustment will depend upon the character of service to which the brakes have been subjected.

While it is a fact that the pressure delivered to the shoes will always be equal, yet paint, grease, oil, or other foreign substance on the brake lining will change the coefficient or friction of the lining to the point where the brakes will be unequal. This inequality can only be remedied by thoroughly cleaning the lining with gasoline or alcohol and roughening the surface with a file or wire brush. If, however, the lining is so saturated with grease or oil that cleaning will not correct the unequal braking effect, it will be necessary to reline the brake shoes.

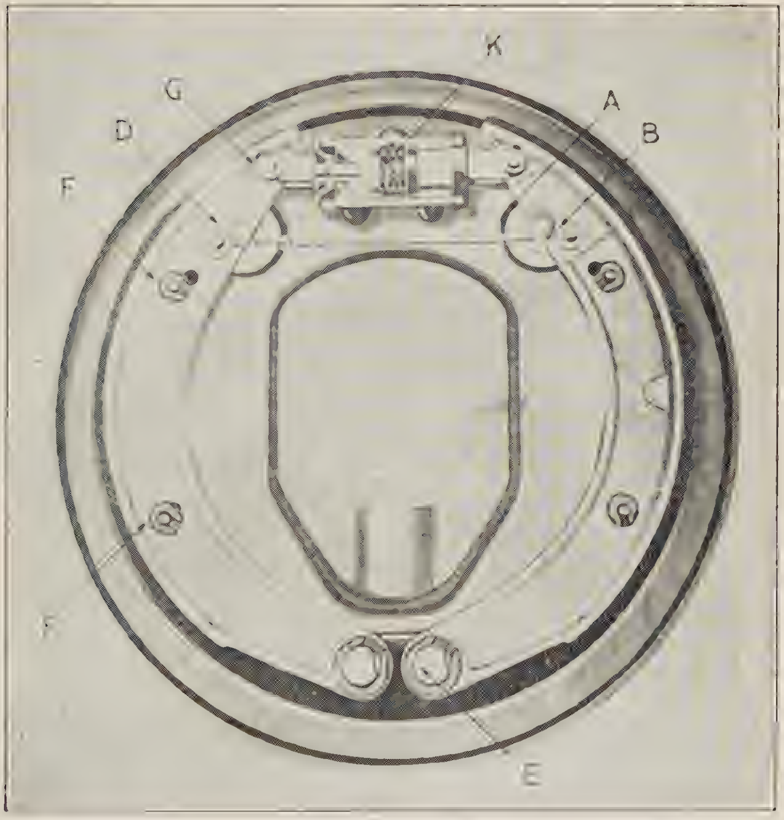


Fig. 52. Wheel Cylinder and Brake Rigging of the Lockheed-Wagner Hydraulic Braking System

Brake Adjustments. When lining wear has reached a point where the foot pedal almost goes to the floorboard, it becomes necessary to adjust the brake shoes into closer relation to the brake drums. Adjustment is made by rotating the adjustment cam *A*, Fig. 52, against the stop pin *B* on the shoes. The tension of the friction spring *D* automatically keeps the cam locked in any position.

To Adjust Brakes. Raise the car on the jack until the wheel is free. Rotate the adjustment nut *C*, Fig. 53, with a wrench until the brake shoe comes into contact with the drum. Now back the adjustment off slightly until the wheel rotates freely without any appreciable drag. Repeat this operation on all eight brake shoes. In Fig. 53 it will be seen that to adjust the shoe into close relation to the drum, the adjustment nut must be turned toward the rim of the wheel when the wrench handle is pointing up. The brake shoe anchor pins *E*, Fig. 52, are eccentric and also points of adjustment but these are set at the factory and should not be changed.

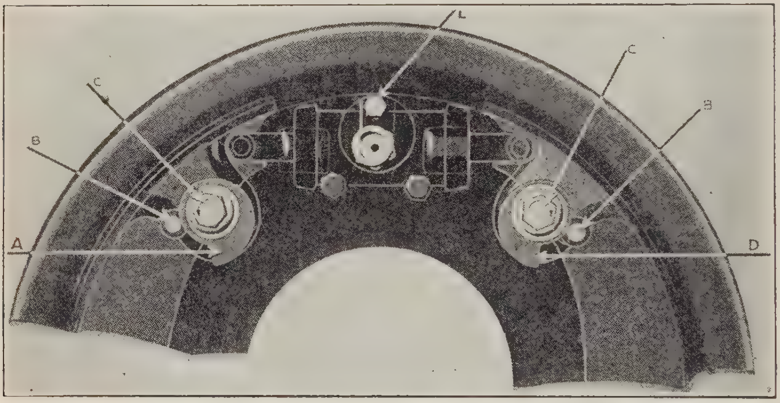


Fig. 53. Adjusting Chart for Lockheed-Wagner Internal-Expanding Brakes

Relining Brakes. When relining brakes, it is imperative that the same kind of lining be used on all four wheels; otherwise the brakes on the individual wheels will not be equally effective in their action.

To Remove Brake Shoes. Remove the *C* washers from the anchor pins *E* and guide pins *F*, Fig. 52. Then unhook the brake shoe return spring, after which the shoes may be pulled off. In assembling, these operations are reversed.

To Remove the Front-Wheel Cylinder. Disconnect the copper tubing from the hose union *A*, Fig. 54, at the frame, then remove the nut *B* and the lockwasher, then the hose union may be removed from the bracket. Rotate the cam adjustments to bring the shoes clear of the wheel cylinder connecting links. Removal of the two cap screws *J*, Fig. 53, holding the cylinder to the brake dust shield, allows the cylinder to be withdrawn from the shield.

To Remove the Rear-Wheel Cylinder. Follow the instructions for the front cylinder except that the copper tubing must be disconnected at the cylinder inlet.

To Remove the Wheel Cylinder Cups. Remove the rubber boots on either end. Withdraw the pistons by inserting a hook in the hole in the skirt of the pistons. The spiral spring placed between the wheel cylinder cups serves to keep the cups in contact with the pistons at all times.

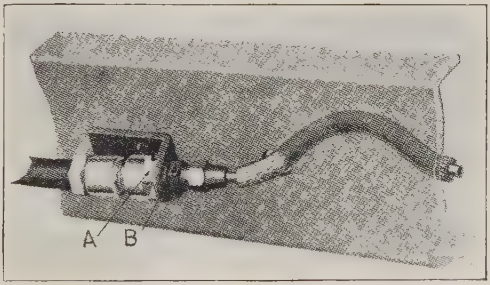


Fig. 54. Bracket Supporting the Hook-Up Union between the Copper Tubing and the Flexible Tube

To Remove the Master Cylinder from the Supply Tank. Take out the drain plug *G*, Fig. 50, in the bottom of the supply tank and draw off the fluid. Disconnect the copper tubes and remove the four cap screws *H* which hold the cylinder in place, and withdraw the cylinder. Remove the lockwire from the end of the cylinder, allowing the master piston, cup, return spring, and the combination valve to be taken out. It should not be necessary to disassemble any cylinder unless it is found to be leaking fluid past the cup.

The cylinder and cup should be cleaned with crocus cloth and washed with alcohol. Do not use kerosene, gasoline, etc. The bore should be free from any score marks, rust corrosion, or pits. It is best to use new cups when servicing a cylinder. Cup and piston should be dipped in brake fluid before inserting into the cylinder.

Bleeding the System. Bleeding the system is necessary only when some part of the hydraulic mechanism has been disconnected. When bleeding, depression of the foot pedal forces the fluid from the master cylinder through the outlet combination valve and thence to the wheel cylinders through the tubing. Since there is no pressure within the system, the master piston return spring will hold the return valve closed, creating a vacuum within the cylinder which causes the cup to collapse at the tip and allow fluid to by-pass from the supply tank, thus refilling the master cylinder.

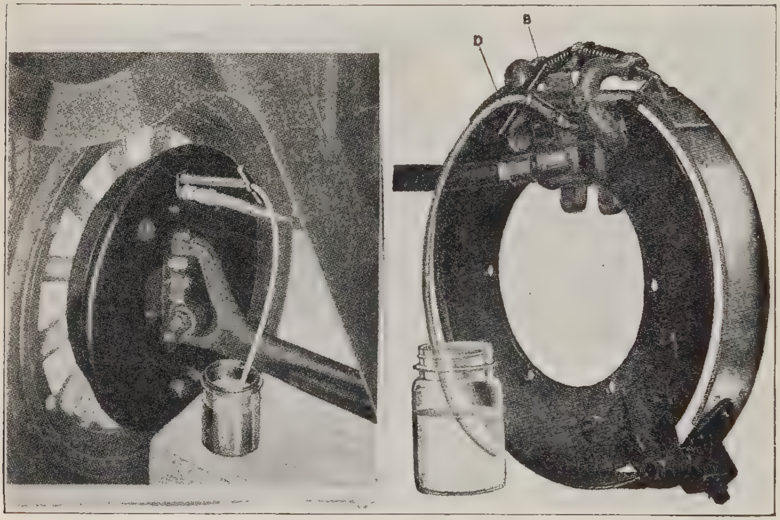


Fig. 55. Bleeding Wheel Cylinders to Remove Air Pockets

Working the foot pedal gives a pumping action which forces fluid through the tubing and out at the wheel cylinder, carrying with it any air that may be present.

To Bleed the Line. Remove the floorboard and unscrew the filler plug *J*, Fig. 50, in the top of the master-cylinder supply tank, exercising care to prevent any dirt getting into this opening. Fill the supply tank with Lockheed brake fluid.

A bleeder screw or valve *L*, Fig. 53, projects at a slight upward angle from the center of each wheel cylinder, the outer end of which is provided with a hexagon shoulder to receive the wrench. The passage through this valve is threaded to receive the cap screw, the head of which is also hexagon shaped. Remove the cap screw with a wrench, after which the nipple at the end of the rubber drain tube may be screwed in place, Fig. 55.

Open the valve about three-quarters turn of the wrench and allow the free end of the rubber tube to hang into a clean container, such as a fruit jar. Depress the foot pedal by hand, allowing the return spring to return the pedal to its released or "off" position. Approximately ten strokes of the pedal will be necessary to bleed each wheel cylinder.

When bleeding, be sure to keep the master-cylinder supply tank more than half full of fluid; otherwise air will be drawn into the system at this point, necessitating re-bleeding. As each wheel cylinder is bled, the bleeder valve is shut off tightly with a wrench; the tube is removed and the cap screw replaced. When the bleeding operation is completed, refill the supply tank and replace the filler plug and screw it down tight.

Caution. Do not use any substitute for Lockheed brake fluid. Lockheed brake fluid is a mixture of neutralized castor oil and denatured alcohol treated with chemical reagents to counteract the action of the fluid on the metal and rubber parts of the system. A substitute may be lacking in these important factors and do much damage to the system. Do not allow grease, paint, oil, or brake fluid to come in contact with the brake lining. Do not clean rubber parts or inside of cylinders with anything but alcohol. Do not use kerosene or gasoline. Do not reline one wheel with a different make of lining than is used on the others, as you cannot expect equal braking effect if this is done. Do not allow the supply tank to be less than half full of brake fluid.

Barrel Type Master Cylinder. The barrel type master cylinder, Fig. 56, is used in conjunction with a dash type supply tank, which is a simple fluid reservoir feeding the fluid to the master cylinder by gravity. The master cylinder consists of a head and barrel casting, valve, piston cup return spring, piston cup, piston, boot, piston stop, and connecting link.

Fluid from the supply tank enters the recessed piston through the vent *O*. Depression of the brake pedal causes piston *B* to move forward in the cylinder barrel. A slight forward movement of the cup *I* blocks the by-pass port *M* and the pressure stroke commences. Actual pressure cannot be built up within the system until sufficient displacement of fluid has taken place to bring all shoes into contact with their drums. Additional pressure on the foot pedal produces the necessary hydraulic pressure required to stop the vehicle. The secondary cup *G* prevents the fluid from leaking into the boot *D*.

Removal of the operator's foot from the brake pedal allows the pedal and connecting link *B* to return independently. The return of the piston *B* and cup *I* is accomplished by the return spring *J*. The return of the piston and cup is much faster in displaced volume than the return of the fluid from the lines. A momentary vacuum is created in the master cylinder barrel, which pulls the fluid through the drilled holes in the piston *B*, and past the lip of the cup *I*. As the normal working fluid returns into the master cylinder from the lines, a surplus is created which is by-passed into the reservoir through port *M*. Thus we have a master cylinder full of fluid for the next brake application.

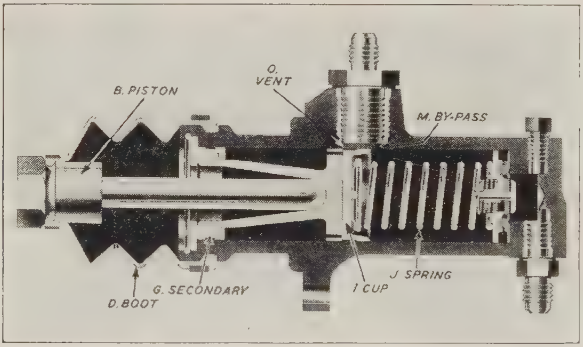


Fig. 56. Barrel Type Cylinder

Integral Tank Type Master Cylinder. The integral tank type master cylinder, Fig. 57, consists of barrel and tank casting, double check valve *L*, piston cup return spring *I*, piston cup *D*, piston *B*, piston stop *P*, boot *G*, and connecting link *A*. The fluid reservoir or supply tank is cast integral over the master cylinder barrel. A combination filler and breather plug *N* permits atmospheric pressure on the reserve fluid at all times. Depression of the foot pedal causes the piston *B* and cup *D* to move forward in the cylinder barrel. A very small forward movement of cup *D* closes the by-pass port *C*, and the pressure stroke commences.

The piston for this type of unit is designed to carry a primary cup *D* and a secondary cup *E*. The construction of the piston is such that reserve fluid from the tank passes through the vent *R* in a recessed area. Thus we have fluid on both sides of the primary cup. The secondary cup *E* is merely a seal to prevent loss of reserve fluid into boot *G*.

Check Valve. A double check valve is used in all master cylinders of the compensating type. It is held in the closed end of the master cylinder barrel by the piston cup return spring. The valve performs two functions. It acts as a seal to prevent fluid or air being drawn into the system through the bleeder screw during the bleeding operation. Fluid passed through the valve on the pressure stroke can return into the master cylinder barrel only by raising the entire valve from its seat. The valve is held in place by the cup return spring. When the pressure on the returning fluid drops below 6 or 8 pounds, the spring closes the valve and the system is under a slight pressure. This pressure will not cause the shoes to drag. It is used to assure a positive seal at the wheel cylinder cup packings. The valve does not control the brake pedal movement. Do not try to remedy this complaint by changing the valve.

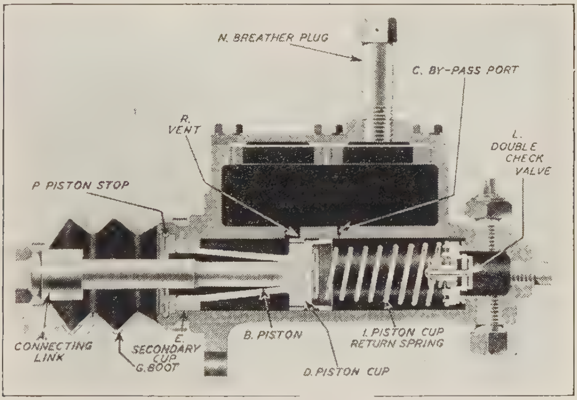


Fig. 57. Integral Tank Master Cylinder

WHEEL BRAKE UNITS

Located at each of the four wheels are wheel brake units. They are composed of a dust shield assembly, or supporting disc, two brake shoes pivoted at the bottom or heel on eccentric anchor pins, a wheel cylinder, and brake shoe retracting spring, Fig. 58. Four types of brake shoes are in use on Lockheed equipped cars. Cast shoe, three-piece shoe, channel shoe, and T-section shoe.

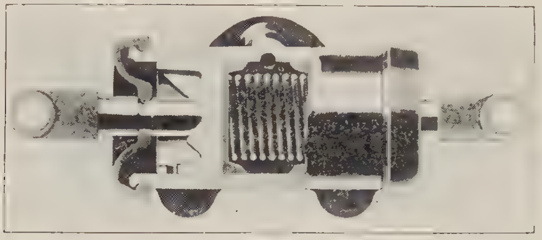


Fig. 58. Wheel Cylinder

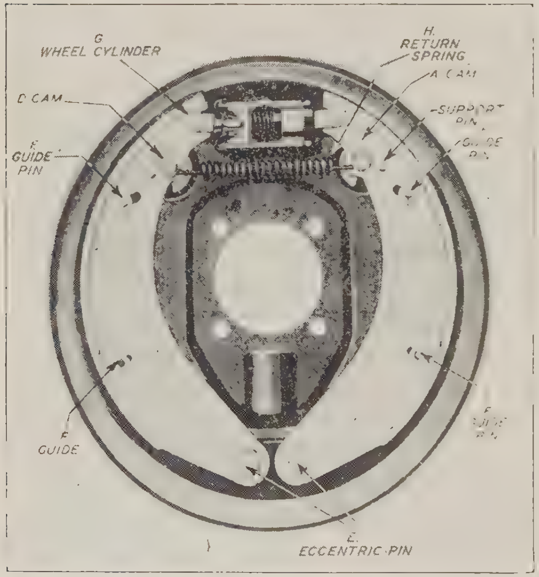


Fig. 59. Cast Brake Shoes

Cast Shoe. The cast shoe, Fig. 59, shows a conventional cast-shoe assembly. The shoes are anchored and pivot on the eccentric pins *E*, and the guide pins *F* act as supports to keep the shoe from chattering and weaving off center line, while return spring *H* holds the shoes in contracted position. Pins support the shoe against cams *A* and *D*, in off position. Wheel cylinder links *G* connect the upper section of the shoes to the wheel cylinder pistons. "C" washers are used on anchor and guide pins to hold the shoes in position. To remove the shoes, remove all "C" washers from the anchor and guide pins, loosen the shoe return spring, swing the shoes outward, and remove the wheel cylinder connecting links.

Three-Piece Shoe. The brake shoes are anchored and pivot on pins (not eccentric). A flat spring acts as a shoe guide and the clamp bolts are designed so that the lower end extends down and strikes the cam in release or off position. The return spring keeps the shoes in retracted position. The upper end of the shoes make contact directly on the wheel cylinder piston. The center pivot bolt is a ream fit, while the clamp bolts are loose fits. With all bolts loose, the sole of the shoe may be pivoted on the center bolt. To remove the shoes, first remove the "C" washers, then the shoe return spring, and swing the shoes out and down.

Channel Shoe. Brake shoes are anchored and pivot on the eccentric pin. The return spring holds the shoe in release or off position against the cam. The shoe guide plates, located at the upper end of the shoe, keep the shoe from weaving and chattering. Yokes and rod serve as a connection between the wheel cylinder piston and the brake shoe. The shoe stop rests on the cam when the brakes are in release position. To remove the shoes, first remove "C" washers *F*, then remove the return spring *H*, and swing the shoes out and down.

T-Section Shoes. Brake shoes are anchored and pivot on eccentric pins. The pins act as guides and remove the tendency to weave and chatter. A return spring keeps the shoes in release or off position against the cam. Links connect the upper end of the shoe to the wheel cylinder. To remove the shoes, first remove "C" washers, then remove the return spring and swing the shoes out and remove the connecting links.

Wheel Cylinder. The wheel cylinder is the unit which changes the applied hydraulic pressure into mechanical force. The wheel cylinder, Fig. 58, is composed of a casting, boots, opposed pistons, opposed cups, and a cup return spring. At the uppermost position and between the piston cups is a bleeder valve used to expel air from the system.

Repairs to Master Cylinders. It may become necessary after lengthy service to remove this unit, hone the cylinder barrel, and replace the cup. The barrel type and integral tank type must be removed from the car when repairs are being made. Repairs may be made on the master cylinder proper of the box type unit without removing the complete assembly from the car. Drain the reservoir by removing the drain plug. Disconnect the lines at the master cylinder. Remove the four retaining cap screws, and the cylinder may then be lifted out of the supply tank.

Repairs to Wheel Cylinders. To remove the front-wheel cylinder, disconnect the copper tubing from the hose union at the frame, then remove the nut and lock washer. The hose union may then be removed from the bracket. Unhook the brake shoe return spring. Removal of the two cap screws holding the cylinder to the brake dust shield allows the cylinder to be withdrawn with the hose. To remove the rear cylinder, follow the above instructions, except that the copper tubing must be disconnected at the cylinder inlet.

Honing Cylinders. When examination of the cylinder shows that the walls are rough or scratched, it is necessary to either repair or replace the unit. It is recommended that the unit be taken to an authorized service station for repairs unless sufficient work of this kind is being done to offset the cost of purchasing the special equipment needed. It is possible to rehone the majority of cylinders for a nominal sum and place them in good working condition. The use of plug gauges and up-to-date honing equipment assures the public the best possible service.

Caution: Cylinders and parts must not be washed in gasoline, kerosene, or oil. In reassembling the unit, all parts must be dipped in Lockheed Fluid (Special No. 5).

Proper Pedal Adjustment—Barrel and Integral Tank Type Master Cylinders. It is imperative that connecting link *A*, Fig. 60, be adjusted for clearance where it seats in piston *B*. There should be ½ inch free movement of the brake pedal pad before the pressure stroke starts. Should *A* be adjusted tightly against piston *B*, port hole *C* will be blocked by cup *D* and the compensating action of the master cylinder will be destroyed. Cup *D* must be clear of port *C* when the piston *B* is in its off or returned position.

Box Type Master Cylinder. Proper adjustment of the brake pedal is made as follows: Remove the clevis pin from the pull rod clevis; adjust the pedal stop screw until the pedal clears the floorboard ½ inch; after the brake pedal has been adjusted to clear the floorboard, loosen the lock nut on the clevis; adjust the clevis until ½ inch free pedal pad travel is obtained before the pressure stroke starts.

Shoe Adjustment (Minor). When the brake lining becomes extensively worn, manifested by foot pedal going almost to the floorboard, and thereby reducing the braking effect, necessary adjustments can readily be made to bring the brake shoes into closer relation with the drum.

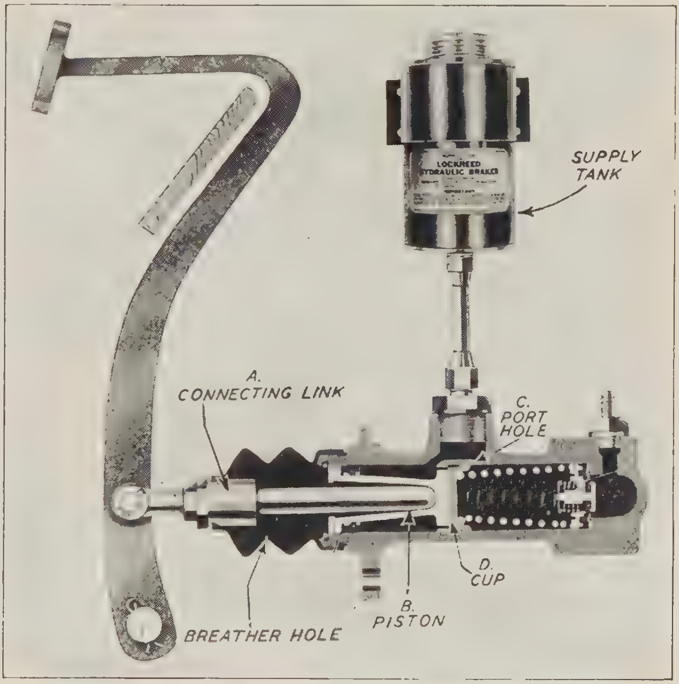


Fig. 60. Pedal Adjusting Diagram

Jack up the wheel to clear the ground. Adjustment is made by rotating the adjustment cam *A*, as shown in Fig. 53, against the stop pin *B* on the shoe. Rotate the adjustment nut *C* with a wrench until the shoe comes into contact with the drum, then back off the adjustment slightly until the wheel rotates freely. Proceed in like manner on the brake shoes of all wheels. To bring the shoe into closer relation with the drum, the adjustment nut must be turned toward the rim of the wheel when the wrench is pointing upwards. The tension of the friction spring automatically keeps the cam locked in any position on most models.

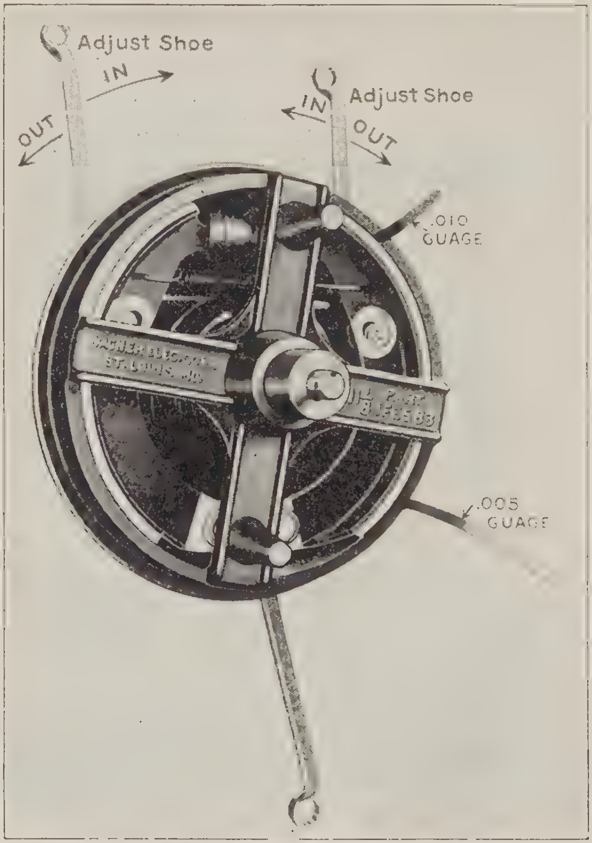


Fig. 61. Adjusting Brake Shoes to Ring Gauge

On some of the later models the friction spring is removed and a lock nut used on the outside of the dust shield. In adjusting this type, it is necessary to loosen the lock nut. This type may be identified by the ½-inch bolt with flats machined on opposite sides to carry the adjusting wrench.

Shoe Adjustment (Major). To readjust the arc of contact to drum cast, channel, and T-section shoes—after relining and reassembling shoes to dust shields—it becomes necessary to readjust the contacting surface of the shoes to the arc of the drums. This is necessary if efficient brakes are expected. To obtain the best results, a dummy drum, Fig. 61, or ring gauge is required if provisions have not been made, such as slotted shields or inspection holes in drums. With the shoe re-assembled and the adjusting ring gauge in place, loosen the anchor pin lock nut (on the rear of the shield). Adjustment is made by turning the eccentric anchor pins *E*, Fig. 59, and rotating adjustment nut until the shoes are set in the proper position. The recommended shoe setting is .005-inch clearance at the heel or lower end of the shoe and .010-inch at the toe or upper end. Clearances are measured with feeler gauge 1½ inches from the ends of the lining. Ring gauges and adaptor bushings may be procured for all types of internal hydraulic brakes from the nearest standard service stations.

HYDRAULIC BRAKE SERVICE AND MAINTENANCE CHART

No. 1. Pedal Goes to Floorboard

Cause	Remedy
A—Normal wear of lining.	When brake linings become worn, it is necessary to set the shoes into closer relation to brake drums. This condition is usually accompanied by the remark that it is necessary to pump the pedal several times before a brake is obtained. Shoes should be set as close to the brake drum as possible without drag. Do not disturb anchor pins when making this adjustment. Adjustment must be made while drums are cool.
B—Brake shoes not properly adjusted.	In cases where the eccentric anchor pins have been disturbed and the relation of the arc of the shoes to drums changed, so that the heel or lower line section of shoe is engaging the drum while the toe or upper section of shoe remains out of contact, a tendency to spring the shoes and distort the drums will result and the necessary pedal movement will allow the pedal to go to the floorboard. Shoes should be readjusted with the aid of a ring gauge.
C—Leak in system.	A leak in the system will allow the pedal, under pressure, to go to the toe board gradually. If no leaks are found at wheels or joints, remove the master cylinder and check bore of barrel for score or scratches.
D—Air in system.	Air in the system will cause a springy, rubbery action of the pedal. Should a sufficient quantity be introduced into the system, the pedal will go to the toe board under normal pressure. The system should be bled.

No. 1. Pedal Goes to Floorboard—Continued

Cause	Remedy
E—Pedal improperly set.	Brake pedals should be set with approximately ½ inch free motion before the pressure stroke starts. Additional free motion reduces the active travel of the master cylinder piston, which, in turn, determines the amount of working fluid to be expelled from the master cylinder into the lines or system.
F—No fluid in supply tank.	The fluid level in the supply tank should be checked at regular intervals. Should the tank become empty, air will be introduced into the system, necessitating bleeding.

No. 2. All Brakes Drag

A—Mineral oil in system.	The introduction of mineral oil, such as engine oil, kerosene, or any fluid with a mineral base, into the system will cause the cups to swell and distort, making it necessary to replace all cups and flush the system.
B—Pedal improperly set.	Directly ahead of the master cylinder piston cup (when in normal release position) is a relief port. It is imperative that this port be open when the brakes are released. The brake pedal should be set with ½ inch free movement before pressure stroke begins. Should this port be blocked by the piston cup not returning to its proper release position, the pressure in the system will gradually build up and the brakes drag. Opening a bleeder screw will allow built-up pressure to escape and give temporary relief. The bleeder screw must be secure before the car is driven.

No. 3. One Wheel Drags

A—Weak brake shoe return spring.	Springs sometimes lose their contracting power and take a set. Replace spring.
B—Brake shoe bearing seized to anchor pin.	Lubricate bearing at anchor pins.
C—Brake shoe set too close to drum.	Readjust shoes to proper clearance. Do not change anchor pin setting.
D—Cups distorted.	In repairing wheel cylinders, if kerosene, gasoline, and other fluids are used as a cleaner, instead of alcohol, the cups will swell and distort. The return action of the shoes will be retarded and the brake drum will heat. Replace cups, wash unit in alcohol, and dip all parts in fluid before re-assembling.
E—Loose wheel bearings.	Tighten bearings.

No. 4. Car Pulls to One Side

A—Grease-soaked lining.	Replace with new lining of same make. Grease-soaked linings cannot be salvaged by washing or cleaning.
B—Shoes improperly set.	All manufacturers advocate a certain shoe setting. The average is .005″ at the heel or lower end, and .010″ clearance at the toe or upper part. The construction of the brake is

No. 4. Car Pulls to One Side—Continued

Cause	Remedy
	such as to cause a slight pull or drift if shoes are improperly set on front wheels. On rear wheels, there will be no drift, but one wheel will slide before the other. Readjust shoes to proper clearance. It will be necessary to use gauge and to shift anchor pin setting.
C—Dust shield loose on axle.	Loose shields permit the brake assembly to shift on the locating bolts. This shifting changes the predetermined centers and causes unequal efficiency. Tighten shields and readjust shoes with gauge.
D—Front spring U-bolts loose.	Loose spring U-bolts permit the axle to shift on the springs and run out of line. This is noticed especially when a high braking torque is developed. Tighten U-bolts at their proper location on spring.
E—Different makes of lining.	Different makes of linings have different braking efficiency. Two different makes, one with high efficiency and one with low efficiency, would cause car to pull to one side.
F—Tires not properly inflated.	All tires should be properly inflated.

No. 5. Springy, Spongy Pedal

A—Brake shoes not properly adjusted.	Consult remedy *B* under No. 1.
B—Air in system.	Consult remedy *D* under No. 1.

No. 6. Excessive Pressure on Pedal, Poor Stop

A—Brake shoes not properly adjusted.	Consult remedy *B* under No. 1.
B—Brake pedal leverage wrong.	Master cylinders of the box type which are mounted to the rear of the brake pedal are connected to same by pull or push rod. This rod is fastened to the master cylinder by an outside lever. The outside lever should be set so that at two-thirds of its active arc it is crossing an imaginary line drawn at right angles with the push or pull rod. A lever so set gives maximum leverage and piston travel.
C—Improper lining.	Improper grades of brake lining lose their gripping qualities after a few thousand miles. As the friction quality decreases, the pressure on the brake pedal is naturally increased to get the equivalent stop.
D—Oil in lining.	Clean or replace lining.
E—Lining making partial contact.	Remove high spots.

No. 7. Light Pressure on Pedal, Severe Brakes

A—Brake shoes not properly adjusted.	Consult remedy *B* under No. 4.
B—Loose dust shield on axle.	Consult remedy *C* under No. 4.
C—Grease-soaked lining.	Consult remedy *A* under No. 4.

BENDIX DUO-SERVO BRAKES

There are only two adjustments to compensate for brake lining wear. These two points at the brakes proper are as follows: First, the eccentric adjustment *A*, Fig. 62, which centralizes the brake shoes in the brake drum. Second, the adjusting screw, Fig. 64, which regulates the clearance between the lining braking surfaces and brake drum to compensate for lining wear.

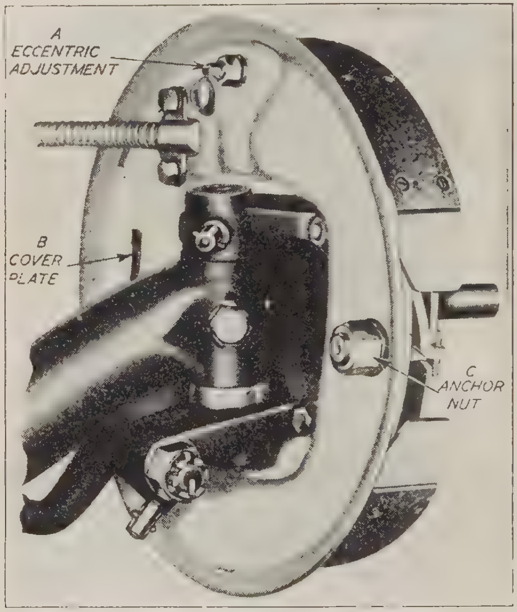


Fig. 62. Backing Plate Bendix Duo-Servo Brake

Shoe Adjustment. Before proceeding with the shoe adjustment, note carefully the instructions under "General Inspection" following. Do not make any changes at points of adjustment of the brake control system to compensate for brake lining wear. The only adjustment is at the brake proper.

With all four wheels jacked up, loosen the lock nut on the eccentric adjustment *A*, Fig. 62. Revolve the wheel into a position so that the inspection hole in the brake drum is about one inch from the adjusting screw end of the lining on the top shoe. Insert a .014-inch feeler gauge *A*, Fig. 63. Turn the eccentric adjustment in the direction the wheel revolves when the car is moving forward until the lining can be felt to grip the feeler gauge when the same is moved in and out. Hold the eccentric in this position and tighten the lock nut *C*, Fig. 62. Revolve the wheel again to see that the brake is free. Make this adjustment at each of the four wheels.

Remove the cover plate *B*, Fig. 62, and with a screw driver or a Bendix special tool, turn the notched wheel, Fig. 64, of the adjusting screw toward the rim of the backing plate (hand moving toward the axle, point of screw driver moving away) until a very slight drag can be felt when turning the wheel over by hand. Then, back off the adjusting screw until the wheel is just free of brake drag. Make this adjustment at each of the four wheels.

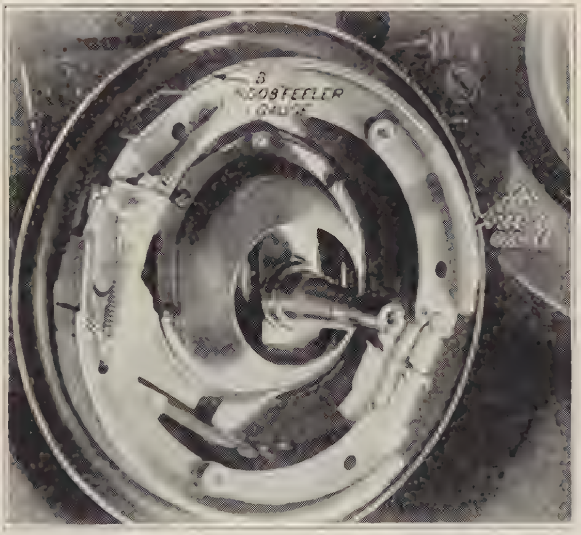


Fig. 63. Showing Points at Which Clearance Is Measured

With the car still jacked up, try the brakes by depressing the brake pedal from 2 to 3 inches, using a pedal jack or other suitable means to hold the pedal in this fixed and depressed position. Try the brake holding effect by pulling each wheel over by hand. All wheels should feel alike. If not, then loosen (not tighten) the adjusting screws on the tight wheels until the brake drag is the same at all wheels. Replace the adjusting screw hole cover plates and lower the car.

General Inspection. When brakes are being relined or the brake system overhauled, with the wheels removed, check the position of the brake shoes at the anchor pin. With the brakes fully released, both shoes should return and rest against the anchor pin. Remove any backlash found present between the shoe-operating lever and the anchor ends of the brake shoes, Fig. 63. This is accomplished by adjusting the cable length or pull-rod length.

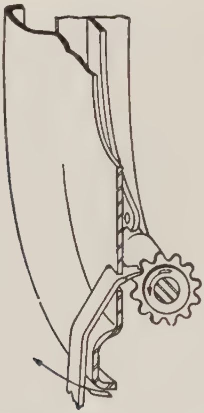


Fig. 64. Showing Adjustment Screw

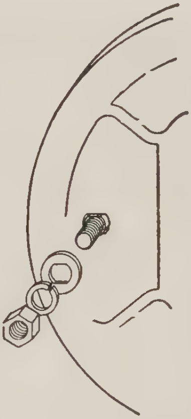


Fig. 65. Showing Anchor Pin Adjustment

Caution. Be sure the brake control system is in the full released position when backlash is being taken up. Be sure also that the cables or rods are not adjusted short so that the shoe-operating lever holds the shoe ends away from the anchor pin. Check the lining wear and if necessary install new lined shoes. Examine the brake lining to make sure the lining is not loose on the shoe. Re-rivet if found loose, provided the lining wear is not excessive. Clean the brake shoe assemblies and drums, removing rust, dirt, oil, or any foreign substance found present. If necessary, adjust the rear axle end play. Check the chassis spring U-bolts. Tighten with a long wrench. Check the chassis spring center bolts. Replace if broken. Check the backing plate bolts. Tighten if necessary. Replace the wheels, making sure that the front hub bearings are properly adjusted and that the rear wheels are tight on the axle shafts.

Anchor Pin Adjustment on All Four Wheels—Single Anchor Type. Adjustment of the anchor pin is necessary only when other adjustments fail to give results, or when the anchor pin nut is found loose, or when fitting relined shoes. Disconnect all four cables at the cross-shaft levers and make sure the cross shaft is returning to its stop. Remove any backlash in linkage between the foot pedal and the cross shaft lever. Loosen the anchor pin nut completely free of the lock washer; note that the anchor pin passes through the backing plate in the elongated holes, as shown in Fig. 65.

Remove the cover plate *B*, Fig. 62, and with a screw driver, or other suitable tool, turn the notched wheel, Fig. 64, of the adjusting screw toward the rim of the backing plate until the two shoes are expanded against the brake drum sufficiently to cause enough brake drag so that the wheel can barely be turned over with both hands. Then, using a soft hammer, tap the anchor pin on the threaded end to insure its assuming a correct position. The anchor pin will shift in the elongated hole when the shoes are expanded and the anchor pin tapped. Tighten the anchor nut *C*, Fig. 62, as tightly as possible with a 16-inch wrench.

With the brake shoes still in expanded position, re-adjust the cable lengths so that the clevis pin will barely enter the clevis and the cross-shaft lever, while holding the cable tight to remove any backlash that might be present at the operating lever. Make this adjustment at each of the four cables. Back the adjusting screw, Fig. 64, until the wheels are just free of brake drag. Make preceding adjustments at each of the four wheels.

A check of the foregoing adjustment may be made as follows: Remove the cover plate from the inspection hole in the brake drum. Check only the secondary shoe clearances. The secondary shoe is the top shoe at a front brake and the bottom shoe at a rear brake. With correct anchor pin and other adjustments properly made, the feeler gauge should show, Fig. 63, approximately twice as much clearance between the drum and brake lining at the adjusting screw end of the shoe as at the anchor pin end of the shoe. A check of about .008-inch clearance at the anchor end and about .014-inch clearance at the adjusting screw end, Fig. 63, will indicate that adjustments have been properly made. After the check and adjustments are made, replace the inspection hole cover plate.

Effects of Oil or Grease on Brake Lining. Much trouble may be eliminated if excessive lubricating of the front wheel bearings and differential is avoided. Where it is found that the brake lining has become over-saturated with oil or grease, the only positive cure against heavy pedal pressure or possibly sensitive brake action will be the replacement of the brake lining. If molded lining is being used, it may be possible to clean the lining with high test gasoline. This will be found to be reasonably satisfactory, providing the grease has not had too long a contact with the lining and allowed to get between the lining and the shoe rim. In the latter case, the lining should be removed from the shoe and cleaned and re-riveted or new lining installed.

TROUBLE SHOOTING ON BENDIX DUO-SERVO BRAKES

Trouble	Remedy
Cars steering unevenly when the brakes are applied.	Balance both front and rear wheels.
	See that both front and both rear wheels will slide together; do not expect all four wheels to slide at the same time.
	Note: The design of the system of leverages in the hook-up mechanism of different cars is such that the percentage of braking power distributed to front and rear wheels is not the same.
	See that all spring clips are extremely tight.
	See that both front tires are inflated to same pressure. Check rear tires also. Examine to see that controls to both front brakes are well lubricated so that each works freely.
Brakes chattering when applied.	Tighten loose spring clips.
	Check and tighten the backing plates if found loose on the axle mountings.
	True up the brake drums if out-of-round more than .010 inch. (Do not remove the drum from the hub of the wheel.)
	If moulded linings are found greasy, clean grease from the lining with high test gasoline.
	Note: There is no sure or permanent cure for trouble from greasy brake linings except by replacement. Brake lining saturants should never

TROUBLE SHOOTING—Continued

Trouble	Remedy
Brakes chattering when applied	be used. Grease cannot be successfully removed by burning the linings with a blow torch.
	Balance all brakes.
	Check the lining clearances and if not correct, make complete readjustment.
Brakes grabbing or locking when applied.	See that the lining is free from grease or oil.
	Adjust any loose wheel bearings.
	Tighten all spring clips.
	See that the anchor pins are located correctly and tightened extremely tight.
	Make sure the lining is tight on shoes.
	Check the brake drums to see that they are not out-of-round or loose on the wheel itself.
	Lubricate all bearings in the entire braking mechanism.
	See that the hook-up releases freely.
	Check and tighten the backing plates if found loose on axle mountings.
Brakes squealing when applied.	Check the brake drums to see that they are not out-of-round or scored.
	See that the lining and drum clearances are properly set up.
	See that the lining is not loose on the shoe. Tighten the rivets.
	Remove noticeable high spots on the surface of the linings with a file.
	See that the lining fits firmly to the shoe, with no bulging between rivets.
	Backing plates must be tight on flanged mountings.
	See that the wheel bearings are adjusted accurately.
Brakes dragging when in a released position.	The brake shoes should be centralized in the brake drum. This can be accomplished by use of the eccentric adjustment. A check showing about .008 inch clearance at anchor end and about .014 inch clearance at screw adjusting end of each shoe will indicate that adjustments have been properly made.
	The brake drums being out-of-round can cause the brake to drag intermittently.

TROUBLE SHOOTING—Continued

Trouble	Remedy
All the brakes but one holding.	Jack up the car and see if this one brake can be taken up more without causing the shoes to drag.
	Check the lining and drum clearances to see that the anchor pin settings are correct.
	See that the front control levers, when the brakes are released, are in their correct positions, as shown in Fig. 67.
	Refer to adjustment instructions for correct setting of rear control levers.
	Check for worn steering knuckle (front wheel).
	Remove grease from lining.
	See that the hook-up is well lubricated.

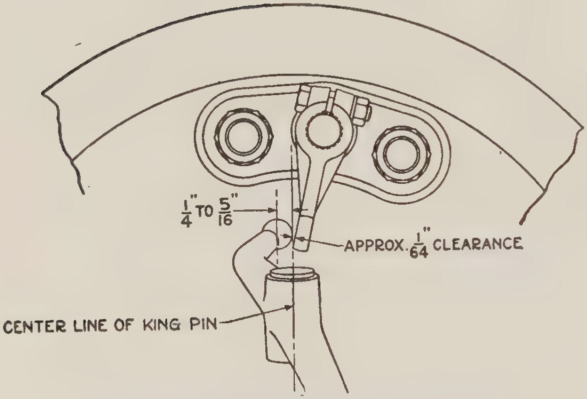


Fig. 67. Proper Alignment of Parts for Lever Type Bendix Front-Wheel Brakes

SERVICING MIDLAND STEELDRAULIC T-SECTION BRAKES

This brake has a one-piece steel band to which the lining is attached. The band or shoe is flexible for about five-eighths of its circumference, the remaining portion having a rib which is integral with the band, forming a rigid T-section for the remaining three-eighths of the circumference. The flexible portion of the shoe is always on the forward side towards which the drum rotates when the car is going forward. This portion of the shoe, being flexible, readily conforms to the drum when the brake is applied, and due to the lining friction, forces the rigid portion of the shoe into contact with the rotating drum thereby multiplying the effort applied to the brake. This wrapping-in action gives rise to the term "self-energizing."

By depressing the brake pedal, the toggle ends, Fig. 68, are spread through the pull exerted on the brake rods and conduit cables. The rigid side of the shoe remains firmly against the anchor pin, due to rigidity and a short extension spring. The flexible side is thus forced into contact with the drum. With the car going forward and the flexible side of the shoe being forced into the drum in the direction of drum rotation, the lining friction greatly assists in forcing the rigid portion of the shoe into contact, Fig. 69. When the car is going backwards, the reverse condition takes place with the flexible end held against the anchor pin. The shoe is always returned to its original position by retractor springs when the brake is released. An adjustable cam *C*, Fig. 70, is attached to the brake apron and bearing against the rigid side of the shoe and is provided for the purpose of centralizing the shoe in the drum.

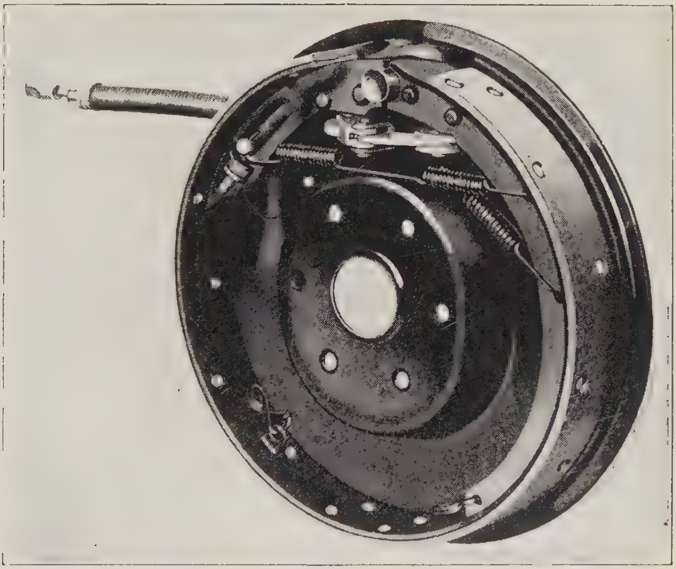


Fig. 68. A Steeldraulic Brake Mounted on Backing Plate

Adjustment of Brakes. The adjusting of brakes should be done in the following three separate and distinct stages. First, take up the slack in the rods or cables to produce the correct anchor pin clearance. Second, centralize the brake shoes in the drums at the centralizing cam. Third, adjust the brakes for equalization at the adjusting nut. Particular attention is drawn to the order in which the adjustments are described and should always be made in the above order. However, before adjusting the brakes, do this first: See that all spring U-bolts are tight. Go over all movable parts of the brake hook-up with oil. See that the tires are inflated to the correct pressure. If the front wheel bearings are loose, re-adjust them.

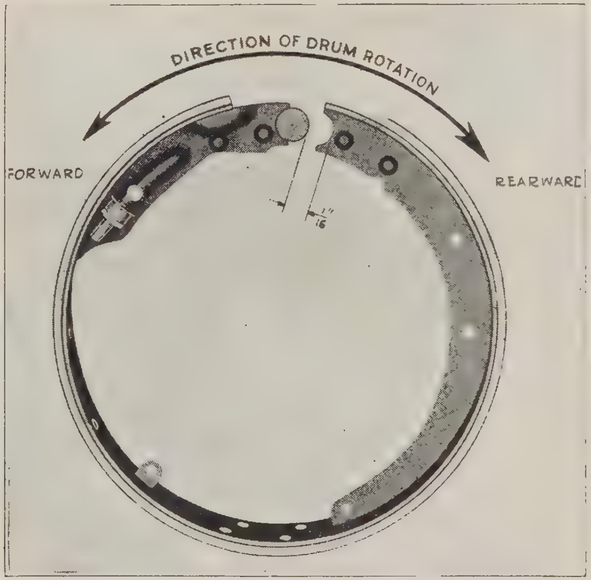


Fig. 69. Showing Effects of Wheel Rotation on Braking

Adjustment of Brake Rods or Cables. The adjusting of the rods or cables, as the case may be, is for the purpose of obtaining $\frac{1}{16}$-inch clearance, Fig. 69, between the adjuster and the anchor pin. See that the brake cross shaft is in full release position before making this adjustment. Remove the inspection hole cover in the drum for the purpose of inserting a feeler to gauge for proper clearance.

Brake Rods. Loosen the jam nut on the rod at the cross-shaft end. Loosen the large jam nut at the conduit end of the rod. Loosen the small rod retainer nut one-half turn if not already loose. Now, by holding the small rod retainer nut with a wrench, turn the rod with the pliers, either into or out of the yoke (as found necessary) until the adjuster on the flexible end of the shoe is pulled away from the anchor pin 1/16 inch.

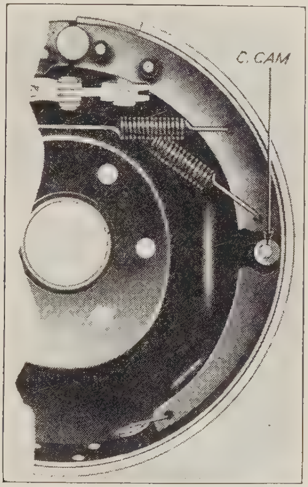


Fig. 70. An Adjustable Cam on a Steeldraulic Brake

Control Cables. At the cross-shaft end of the brake cable, hold the cable adjuster ferrule with the wrench and loosen the lock nut, then turn the short brake adjuster rod, Fig. 71, either into or out of the ferrule until 1/16-inch anchor pin clearance is obtained. All four brakes are set individually and in a like manner. When the adjustment is completed, tighten all locking nuts. Lack of clearance between the anchor pin and the adjuster will cause rattle in the rods and play in the brake pedal.

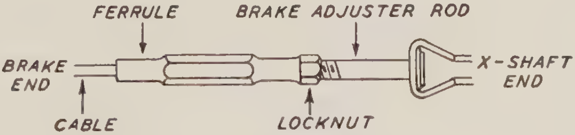


Fig. 71. Adjusting Cables

Centralizing Brake Shoes in Drums. Turn the wheel until the inspection hole is directly over the brake shoe centralizing cam. This cam *C*, Fig. 70, is located on the brake apron 90 degrees from the anchor pin on the rigid side of the shoe. Insert a .015 to .025-inch feeler between the brake shoe and the brake drum at the centralizing cam. Back off the centralizing cam lock nut on the back of the brake apron until the tension is released. Turn the centralizer cam until the brake shoe is forced over toward the brake drum enough to tighten the feeler between the shoe and the drum. Hold the cam in this position and tighten the lock nut. This operation should be done on all four wheels. Insufficient clearance between the lining and the drum causes drag.

Adjusting Brake Shoes for Equalization. With the car still on jacks and using a pedal jack, depress the brake pedal to approximately half of its total travel. Remove the adjusting hole cover on the brake apron. Using the brake adjusting tool, turn the brake adjusting nut on each of the four brakes until the wheel can just be turned forward by hand against the brake action. Turning the brake adjusting nut clockwise, with reference to the anchor pin, increases the brake drag. This drag should be the same on all wheels. The wheels should turn freely when the brake pedal is released. Unless these clearances are maintained, high or low pedal reserve will become noticeable. Pedal reserve is the amount of pedal travel left after the brakes begin to contact the drums. Take the car off the jacks and test the brakes on a dry level floor or pavement to make sure the brakes are equalized. If any of the brakes are too tight, they may be relieved by turning the adjusting nut counter-clockwise, with reference to the anchor pin, and loose brakes may be tightened by turning the adjusting nut clockwise. Usually one or two notches is all that is required for balancing. When adjustments are completed, replace the inspection and adjusting hole covers.

SERVICING CHEVROLET HUCK TYPE BRAKES

These brakes, Fig. 72, are representative of the Huck type brakes used on many models of General Motors cars. When servicing the Chevrolet brakes, first, disconnect the pedal pull-back spring, brake pedal pull rod, and front and rear adjustable pull rods. Next, loosen the cross-shaft bracket nuts. Check to see that the cross shaft is free. Lubricate if necessary. Insert the brake-adjusting gauge as illustrated at *A*.

Set the brake pedal against its stop and adjust the pedal pull rod to its proper length, making sure the clevis pin *B* is in extreme forward position, and connect the pull rod. Hook up the pull-back spring. Remove the gauge and be sure that the shaft is in the center of hole *C* in the emergency brake cross-shaft bracket. Tighten the cross-shaft bracket nuts. Check the front-brake cross heads to see that they operate freely. Lubricate if necessary.

Adjust the front adjustable pull rods and rear adjustable pull rods to their proper length, so that the cam-operating levers *D* are against their stops *E*, and connect the pull rods. The front brake cables must be adjusted so there is no slack in them. This is done by pulling back on the rear end of the cable, so that the pull does not quite move the cam-operating levers *D* and screwing rod into the cable end.

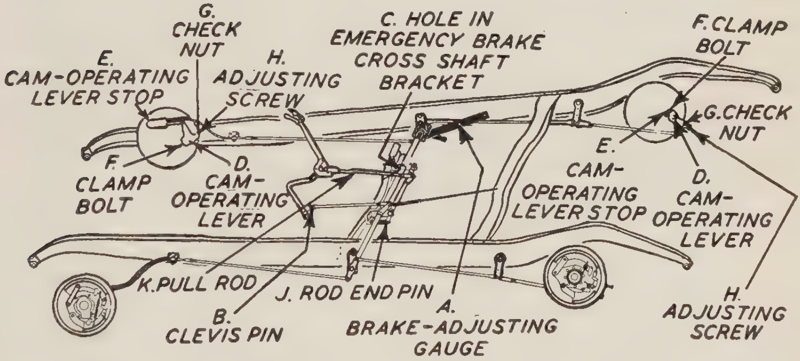


Fig. 72. Showing Chevrolet Huck Type Brakes

Re-Centralizing Brake Shoes. Adjust the front wheel bearings to the proper tension and loosen all centralizer clamp bolts *F*. Make sure that the centralizers are free to move by tapping lightly up and down on the adjusting lever hub nut with a hammer or wrench. Give the brake pedal a hard, quick push and release; clamp up the centralizer bolts *F*, maintaining a moderate pressure on the pedal. Make sure that the centralizer bolts do not move while performing this operation.

Front and Rear Brake Shoes. Jack up all four wheels and loosen the check nuts *G*. Turn the adjusting screws *H* to the right until the brake shoes drag very lightly on the drums. Tighten the check nuts *G*. Check the brakes for equal braking power, left and right side, slacking off on the side which pulls the harder until they are equal. This should be done on a level, clean floor or on the crown or center of a road.

Parking Brake Lining. Set the hand-brake lever in the extreme forward position. Set the rod end pin *J* in the extreme rear position and adjust the pull rod *K* to its proper length.

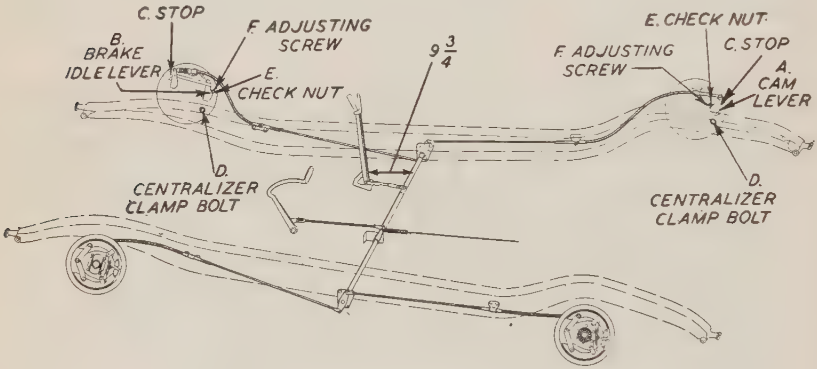


Fig. 73. Chevrolet Standard "DC" Model Brakes

SERVICING STANDARD MODEL 1934 CHEVROLET BRAKES

First, disconnect the pedal pull-back spring, brake pull rod, front and rear pull rods, and hand-brake pull rod, Fig. 73. Next, set the hand-brake lever to its extreme forward position and adjust the hand-brake pull rod to its proper length—9⅜ inches between centers. This can be accurately measured from the back of the front hole to the back of the slot. Assemble the pull rod to the hand-brake and cross-shaft levers. Hook up the pull-back spring and set the brake pedal stop so that the brake pedal clears the floor board ¼ inch. With the brake pedal against its stop, adjust the pedal pull rod to its proper length. Connect up the pull rod.

With the cam levers *A* and the brake idler levers *B* against their stops *C*, adjust the front and rear brake rods to their proper length. The front brake cables must be adjusted so there is no slack in them. This is done by pulling back on the rod end of the cable so that the pull does not move the cam levers *A* and screwing rod into cable end. Connect up pull rods.

Check to see that the front wheel bearings are in proper adjustment. Loosen all centralizer clamp bolts *D*, making sure that centralizers are free to move by tapping up and down on the adjusting lever hub nut with a hammer or wrench. Give the brake pedal a hard quick push and release, then maintaining a moderate pressure on the pedal, clamp up the centralizer clamp bolts *D*. Jack up all four wheels and loosen the check nuts *E* and turn the adjusting screws *F* to the right until the brake shoes drag very lightly on the drum. Tighten check nuts *E*. Try the brakes for equal braking, left and right and slightly slack off the brake that pulls the harder. Road test the car, apply brakes slowly to check action of brakes at light, medium, and maximum pedal pressures. Be sure that all brake rod pins are securely cotter pinned. The instruction here given is for the Chevrolet 1934 passenger car. Construction of the 1934 "Master Model" is similar but control mechanism differs.

FORD "V-8" BRAKES

OPERATION, ADJUSTMENT, AND REPLACEMENT

In adjusting the brakes on Ford "V-8" cars, the adjusting screw B-2041 should be turned in until the brake shoe starts to drag on the drum and then backed off one or two notches until the wheel turns freely. The brakes must be cold when these adjustments are made for if the brakes are adjusted while the drum is hot they will not be free when the drums have cooled off. An ideal setting is obtained when all four tires start to skid at the same time, when the brakes are applied, and while the car is traveling at a speed of approximately 25 miles per hour on a dry pavement.

As the pressure applied to the brake is distributed equally to all four wheels, any difference in the coefficient of friction of the brake lining in the various brake drums reflects in the performance of the brake. For this reason, it is important that the same type of lining be used on all wheels. It is also of extreme importance that these linings be free from grease and oil. The use of the correct front wheel lubricant and the periodic removal of any surplus lubricant from the differential, as well as the replacing of grease retainers when leakage is indicated, will prove particularly valuable in maintaining brake efficiency. On the system of brake linkage used on all Ford cars, Figs. 74 and 75, the rod adjustment must be maintained for each wheel individually.

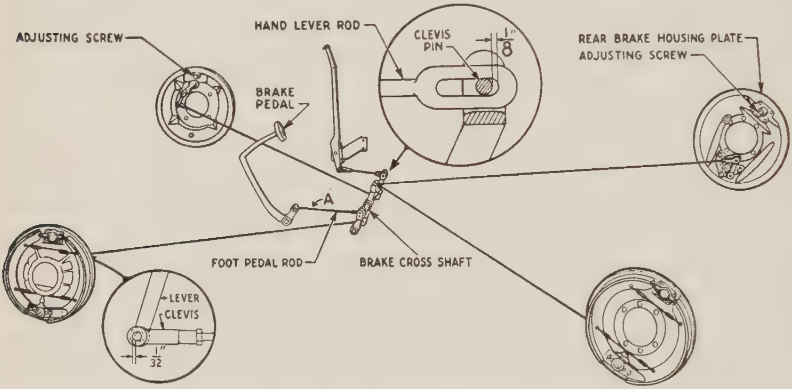


Fig. 74. Ford "V-8," 1935, Brake System (Car)

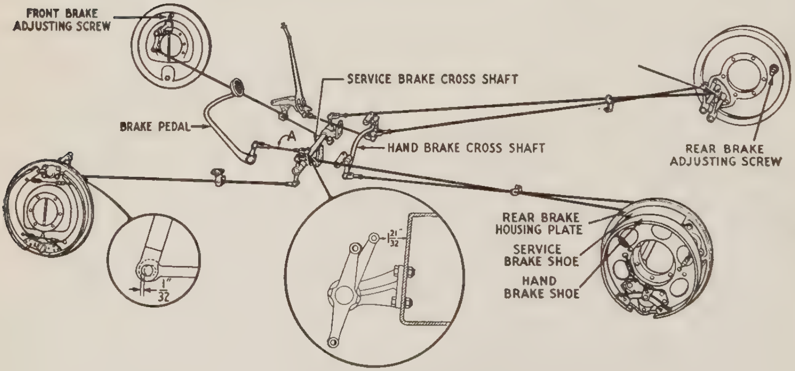


Fig. 75. Ford "V-8," 1935, Brake System (Truck)

Adjusting Brake Rods. To adjust the rods, proceed as follows: Disconnect the rods from the brake levers at all four wheels and from the brake pedal. Move the hand-brake lever to the extreme forward, or release position. The levers shown in circle, Fig. 74, on the end of the brake cross shaft should now be in an exactly vertical position. On the truck, the upper end of these levers will be to the rear of the true vertical position, approximately one inch. See insert, Fig. 75. Next, each rod connecting the cross shaft to the brake lever on the housing plate should be pulled toward the wheel enough to take up all the play, while the lever should be pushed toward the cross shaft enough to take up all the play in the cam, etc., in the housing plate.

The length of the rod should now be adjusted so that the pin hole in the rod is 1/32-inch nearer the cross shaft than the hole in the lever on the brake unit. See insert Figs. 74 and 75. The pin should then be replaced and a new cotter pin installed. It is always good practice to bend each side of all cotter pins in opposite directions as an extra precaution against their dropping out. This 1/32-inch adjustment gives the maximum brake pedal adjustment and places a slight tension on the entire system. Under no circumstances should more than 1/32-inch be used in making this adjustment, as this would defeat the purpose of the design. Adjust the brake pedal to cross-shaft rod so that the pedal is held against the rubber stop on the floor board. Incorrect brake rod adjustment results in dragging, chattering, and squeaking brakes and unequal braking action.

Testing the Brakes. In road testing the brakes on the Ford cars and trucks, (the ideal setting is when there is the least possible pedal pressure), all four wheels will slide at the same time when the car is traveling at a speed of 25 miles per hour. Due to the difference in the distribution of weight at the different speeds, it will be noted that at speeds above 25 miles per hour the rear wheels only will slide at this adjustment, while at the lower speeds it will be noted that in emergency stops, where the maximum pressure is placed on the pedal suddenly, only the front wheels will lock. This is the best adjustment possible for maximum braking efficiency at all speeds. The brake testing machine may be used to secure these same settings.

Water in Brakes. After washing cars, brakes should be tested and if the lining has become wet the owner should be advised that the braking efficiency is below normal until the brakes have dried. Do not let the car stand over night with the hand brake set if the brakes are wet.

Overhauling the Brakes. When disassembling the brake shoe, practices which are apt to distort the shoe should be avoided. The rib of the brake shoe should always be supported when removing the brake shoe pin. These pins are pressed into the shoe tightly and serious distortion of the arc of the shoe is liable to result if the pins are driven out with the rib unsupported.

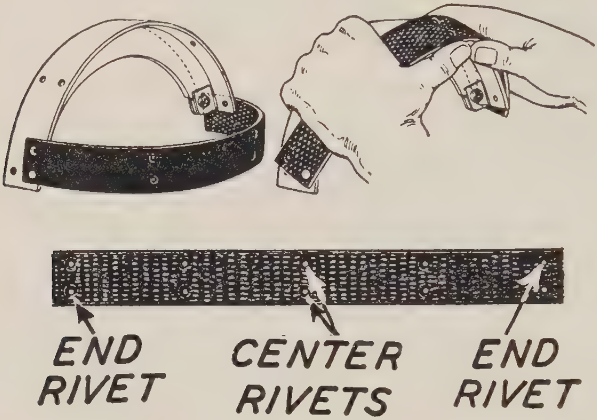


Fig. 76. Applying Lining

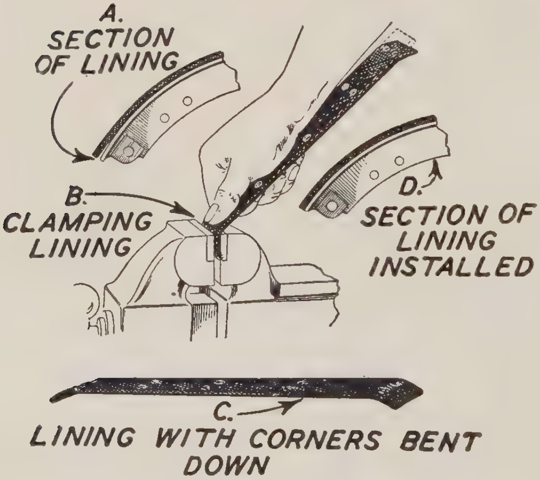

A. SECTION OF LINING
B. CLAMPING LINING
D. SECTION OF LINING INSTALLED
C. LINING WITH CORNERS BENT DOWN

Fig. 77. Preparing Lining

Installing Lining. Fig. 76 shows a method of installing the brake lining on brake shoes. To install the lining, proceed as follows: With the arc of the brake lining at right angles with the arc of the brake shoe, install one rivet over another rivet at each end of the opposite edges of the lining, as shown in Fig. 76. The lining can then be pushed up over the shoe and the balance of the rivets installed, starting with the two center rivets Fig. 76. The lining, when correctly installed, will conform with the arc of the shoe, fitting tightly at all points. Should you find that the ends of the lining pull away from the brake shoe as shown by the arrow in section *A*, Fig. 77, this may be corrected as follows: First, clamp a vise on the end of the lining on the center line of the end rivet hole, then slightly bend the corners down as shown at *B* and *C*, Fig. 77. If reasonable care is used not to break the lining, the result will be as shown in *D*, Fig. 77.

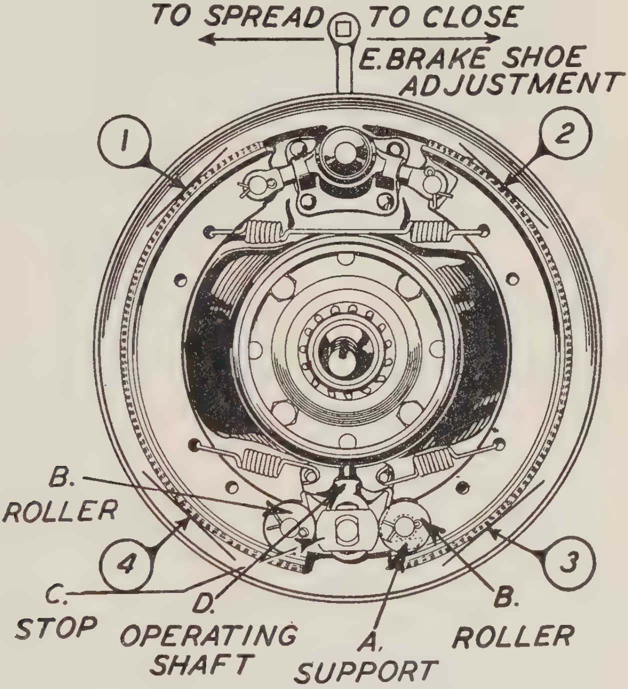


Fig. 78. Grinding Ford "V-8" Lining

Grinding the Lining. The brake shoe is now ready for grinding, one method of which is shown in Fig. 78. The importance of this operation cannot be overemphasized. The brake shoes are held in a nonadjustable fixed position when released. If the arc of the brake shoe is not ground to the correct radius with relation to the pin holes in the shoe proper, dragging brakes when released, or incomplete contact when applied, will result. The use of the grinder, which locates from these holes and grinds to the specified radius, is absolutely essential for maximum efficiency.

First, remove the clevis pins from the pull rods so that the rollers *B* seat firmly against stop *C*, Fig. 78. Turn the grinding disc to position (1) and adjust brake shoe at *E* until the lining just touches the grinding disc. Next, turn the grinding disc to positions (2) and (3). If position (3) is too tight, remove the lower end of the brake shoe and bend support *A* up. Replace brake shoe and check both positions (2) and (3) again. When this shoe is properly adjusted, repeat the same operation on the opposite brake shoe and then grind. If all high spots do not grind off, spread the brake shoes at *E* and grind again. Replace the brake drum and adjust the pull rod so that all slack is out, but be sure the drum turns freely. Even with careful adjustment and centralizing of the brake shoes, it often requires grinding several thousandths off at the high spots before there is a fully ground surface.

Checking for Dragging Brakes. Many mechanics keep on hand a front and rear hub and drum assembly which has been cut out to permit the use of a feeler gauge between the brake shoe and the drum. This is a very good method of checking for dragging brakes as it removes the human element or guesswork which is necessary when they are checked by feel alone. In using this method of checking, a .005-inch feeler should pass clearly between the lining and the drum at all points. Be careful when checking badly-worn drums.

Chattering brakes are usually caused by either incorrect rod adjustment, oil soaked linings, loose wheel or spindle bearings, or brake housing plates loose on the axle. Squeaking brakes are usually caused by incorrectly ground brake shoes or faulty adjustment of the brake or oil-soaked linings.

Two Ford gauges, AB-117 and AB-118, have been designed for checking the concentricity of the brake assembly and are provided with an adapter which permits the checking of both 11-inch and 12-inch brakes. When checking either brake assembly for concentricity, a .010 inch feeler should pass freely between the gauging surface and the lining at all points around and across the assembly. The clearance between the lining and the gauging surface should not be greater than .030-inch at any point, with the exception of the area at the immediate ends, as shown in Figs. 79 and 80.

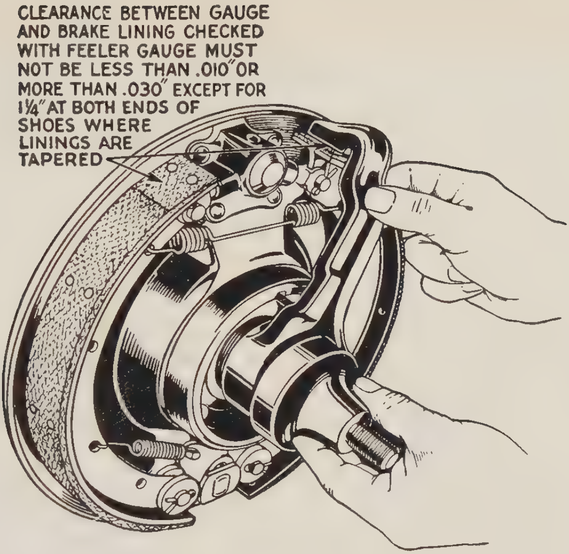

CLEARANCE BETWEEN GAUGE AND BRAKE LINING CHECKED WITH FEELER GAUGE MUST NOT BE LESS THAN .010″ OR MORE THAN .030″ EXCEPT FOR 1¼″ AT BOTH ENDS OF SHOES WHERE LININGS ARE TAPERED

Fig. 79. Checking the Front Brake

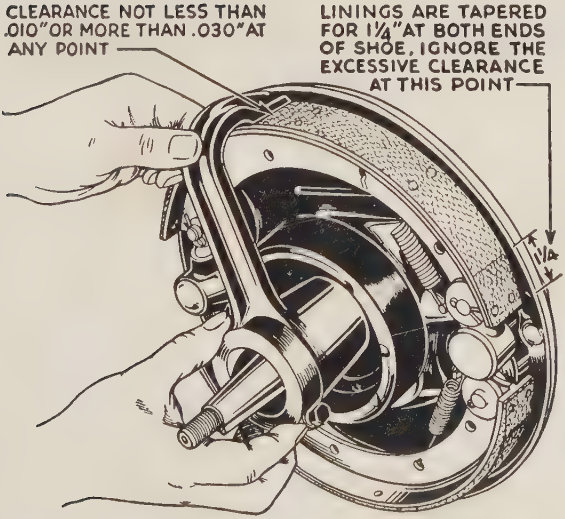

CLEARANCE NOT LESS THAN .010″ OR MORE THAN .030″ AT ANY POINT
LININGS ARE TAPERED FOR 1¼″ AT BOTH ENDS OF SHOE, IGNORE THE EXCESSIVE CLEARANCE AT THIS POINT
1¼

Fig. 80. Checking the Rear Brake Assembly for Concentricity

Groaning and Chattering Brakes. Groaning and chattering of the brakes is caused by one or several of the following conditions. Incorrectly adjusted brake rods or wheel bearing, loose spindle pin bearings, brake housing plate loose on spindle or axle, incorrectly distributed clearance between the lining and drum. In the assembly, the shoes should have more clearance at the operating side (bottom of front assembly and front side of rear assembly) than on the adjusting side. This is important for maximum performance.

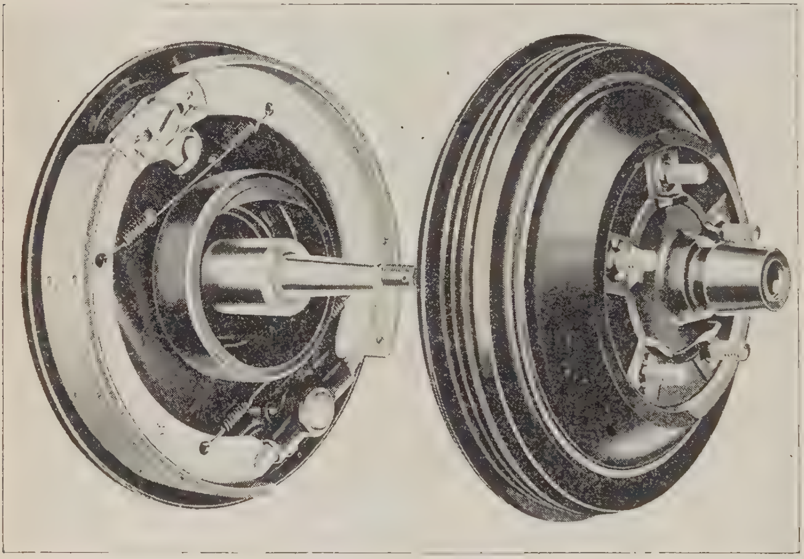


Fig. 81. 1935 Ford "V-8" Brakes

By means of the adjusting screw, set the adjusting end from .010- to .015-inch clearance, and then check the clearance all around the assembly. If the clearance at the operating end is less than .020 inch, install B-2045BR brake shoe pins with oversize heads. These pins raise the shoe .020 inch and increase the clearance an equal amount and are identified by a small countersink in the head.

1935 Ford "V-8" Brakes. The mechanical braking system has brake shoes of the self-centering type, these being shorter and wider to more effectively utilize the available braking surface. In place of short lever arms attaching the shoes to the backing plate pin, slotted pins are used, within which the webs of the shoes fit. This design permits the shoes to slide vertically. A "floating wedge" or cam is used in the shoe expanding mechanism, Fig. 81, both front and rear, so that the shoes can center themselves within the drums. The braking area is 186 square inches, providing large braking surface for a car of this weight. The brake drums have a number of cooling ribs and are of alloy-iron. The shoe actuating shafts are placed at right angles with the brake rods, so that a direct pull is exerted on the shaft levers. The brake cross shaft is mounted on brackets attached to the X-members at a point located in front of the center box-member of the frame. The location of the shaft coincides closely with the centers about which both front and rear axles move, namely the ball joint of the front radius rods and the forward end of the torque tube. The linkage is practically free from the influence of axle motion, and is equally effective in either the forward or backward motion of the car. The distribution of braking force between front and rear wheels is normally set at 50 per cent — 50 per cent.

TRANSMISSION BRAKES

The transmission brake is ordinarily of the exposed type. In reality it is not a transmission brake but takes its name from its application to the propeller shaft just back of the transmission. Ordinarily the brake drum is pulled from the car with the transmission. Brakes when used in this position are used as emergency brakes and are connected with the hand brake. For a number of years the Franklin Motor Car Company made use of a brake drum in this location for the service brake.

The Ford Model "T" car foot brake was connected with the transmission drum and was a real transmission brake. Some trucks and buses make use of drums located in connection with the transmission or propeller shaft for service brakes. In such cases the brake drums are very heavy and are designed for the dissipation of heat.

Care of Brake. The transmission brake has a very powerful action owing to the fact that the braking effort is multiplied many times over, due to the gear ratio between the pinion and ring gear. However, the hand brake is used so seldom that it is frequently neglected so that when an emergency does arise, it is of little worth. Possibly the most frequent cause of transmission brake failure is the saturation of the brake lining with grease thrown off from the transmission. Brake lining so saturated either refuses to hold at all in case of an emergency or, if it does hold, is likely to generate so much heat that the oil starts to smoke and may even burn.

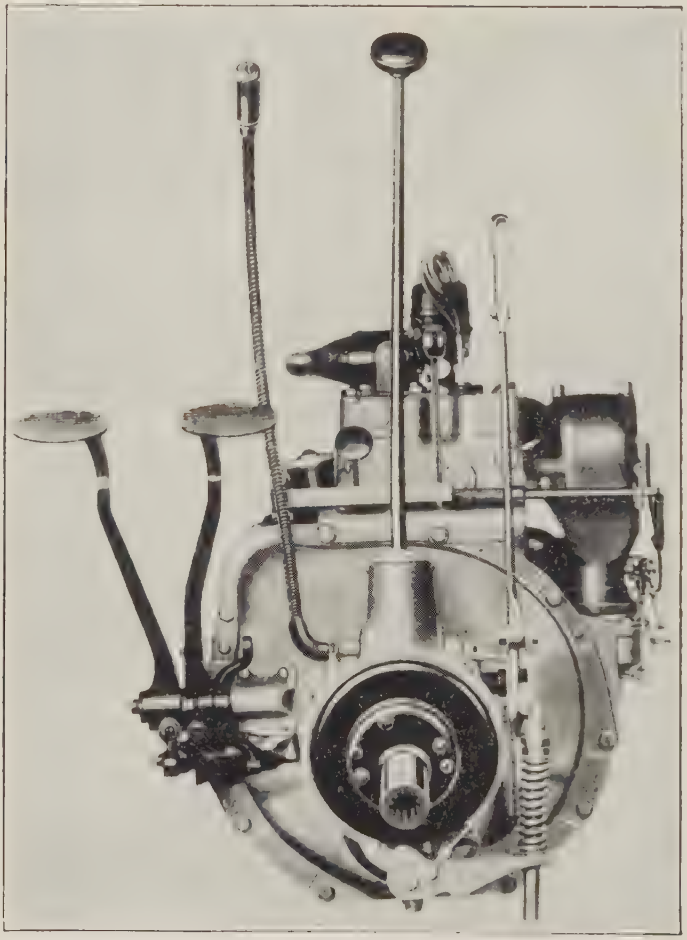


Fig. 82. Pontiac "Big Six" Transmission Brake for Hand Brake Use

The most important point of care then, with reference to the transmission brake, such as that illustrated in Fig. 82, is seeing that grease does not collect on the lining or drum. The next important feature is seeing that the brake lining is in good condition and does not wear unevenly. Perhaps the most important of all is to see that the brake adjustment is properly made so that the application of the hand lever will cause positive holding effort. Brakes such as this, when in good condition and properly adjusted, slide the rear wheels with very little effort on the part of the driver.

Servicing. When a job of brake work comes into the shop, the owner should be asked about the emergency brake and, if it is not satisfactory and safe, he should be urged to authorize servicing it. The usual service points are suggested below.

First, check for grease or other dirt accumulation, and clean if necessary. Follow this inspection by the inspection of the brake lining clearance. This should not be less than .010 inch or .012 inch nor more than $\frac{1}{32}$ inch. Do not set up the brake lining clearance too close, since the drum will expand under heat and may cause binding or dragging.

If the lining is worn thin in spots or if it is saturated with grease, it should be replaced with new lining.

Check over the brake handle and the brake handle pawl or dog and the ratchet. It is of utmost importance that these be in good condition, because if they are not, the parked car may have the brakes jarred off by passing traffic and the car "run wild" if parked on a hill. Finally see that the springs used in connection with the brake are in good condition and that all parts are in proper alignment and properly lubricated so that the brake action is easy and at the same time positive and forceful.

BENDIX DUO-SERVO HYDRAULIC BRAKES

Fig. 83 illustrates the type of hydraulic brake supplied by the Bendix Corporation for use on Nash automobiles. It will be noted that a double end cylinder is utilized, and that both the rear and forward shoe of the Bendix Duo-Servo mechanism are operated when the brakes are set. This construction is quite similar to the mechanically operated duo-servo brakes, since the two shoes are tied together at the ends opposite the cylinder, and since any tendency of one shoe to rotate is transferred to the other one, thus assisting in setting the brakes.

Sealing Brakes against Water. The effect of water or dampness upon the action of brakes is well known to all students of auto mechanics. In the first place, it is necessary to have a brake lining which does not have an affinity for moisture. That is, one which will not absorb moisture from the atmosphere when the car is standing. The construction of such brake lining is not so simple as engineers will tell you. However, this is a matter about which the auto mechanic can do nothing. The best he can do is to help maintain the lining with which the car is equipped, and the water sealing devices provided, in good order. Naturally, of course, he understands that when he is selecting linings for a job, the lining which is impervious to water should be used. In some instances it may be necessary for the auto repairman to instruct his customers in the practice of "burning out" water from the lining, when their car is first taken from the garage, if their car is subject to the effects of moisture accumulation. This is easily done by driving the car, let us say, in second-speed gear, and holding the brake shoes in contact with the drums so as to warm them up and dry the moisture out of the lining. This should be done on the level and when the roadway is clear, so as to have the brakes in proper condition for ordinary usage or an emergency stop.

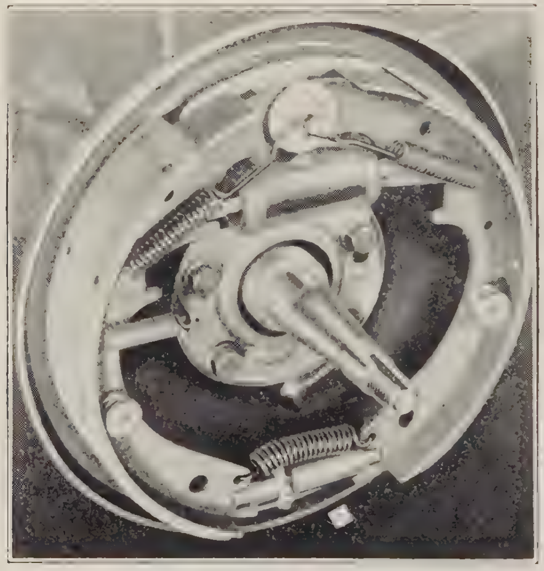


Fig. 83. Nash Bendix Duo-Servo Hydraulic Brakes

Fig. 84 shows the 1935 Pontiac hydraulic actuated rear brake drum assembly in part sectioned view. This brake is provided with what is termed a triple seal. The first seal is so designed that any water thrown by the wheel on the opposite side of the car will be shed or carried away from the drum edge, which is underneath the first seal. Directly under the edge of the drum, is the second seal, which is part of the backing plate and of course must be maintained a slight distance away from the edge of the drum itself. The third seal is included within the backing plate in such manner that any water which should accidentally find its way past the first seal will be caught and drained out before it actually comes in contact with the brake lining.

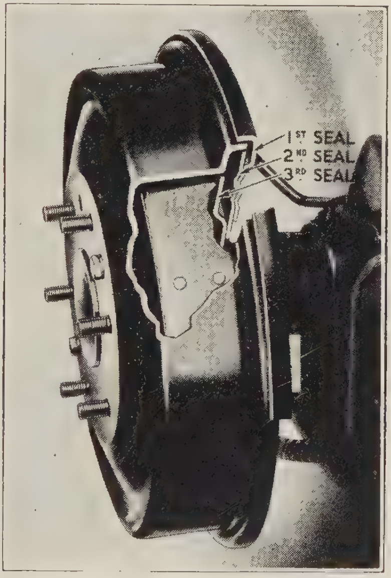


Fig. 84. 1935 Pontiac Triple-Sealed Brake Drum

HUDSON-TERRAPLANE BRAKE CONTROL SYSTEM

Fig. 85 illustrates the Hudson-Terraplane brake control system which is operated by means of cables. The hand-brake lever has been set to the side of the car, this serving to entirely clear the driving compartment of levers, since levers are not used in connection with transmission gear shift of the 1935 cars. The brake shoes are of the Bendix Duo-Servo type and both foot and hand levers work on the same set of controls.

Fig. 86 shows the center control which is of the rotary equalizer type. A study of this figure will show that the action of the foot pedal is somewhat different from former designs. That is, when the foot pedal is pushed down, the lever, being below the fulcrum point, serves to push the foot-pedal brake rod rearward, and this in turn serves to rotate the rotary equalizer mounted on a pin at the center of the brake rigging. Pulling on the hand brake serves to pull the opposite end of the equalizer forward, so that it always rotates in

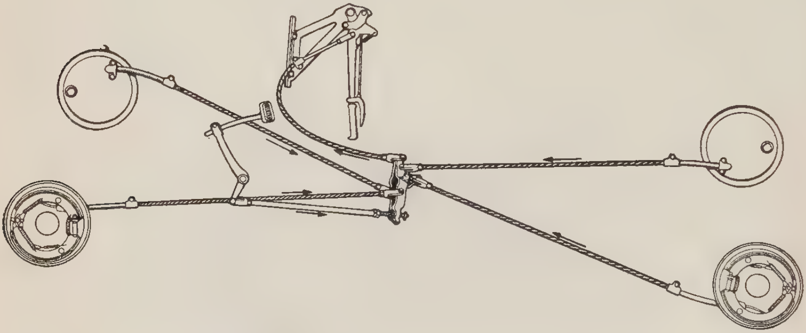


Fig. 85. Brake Lay-Out Used on Hudsons and Terraplanes—Provides Exact Braking Control at All Speeds through the Rotary Equalizer

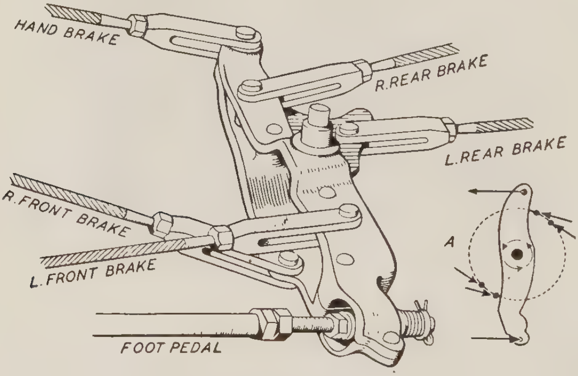


Fig. 86. The Rotary Equalizer Provides Exact Proportion of Braking Effort on All Four Wheels

the same direction when the brakes are set by either hand or foot means.

Arrows pointing to the lever across the rotary equalizer shown at *A*, Fig. 86, indicate the direction of movement of the several parts connecting to the rotary equalizer. All cables are marked in the illustration, Fig. 86. Note that these cables are disposed about what might be termed a circle, as indicated by the dotted line at *A*. The geometrical design on which this device is laid out, serves to provide exactly the same amount of brake-cable movement for all of the four brakes so that when the brakes are properly equalized the operation of the foot or hand lever serves to deliver exactly the same amount of motion to each of the brake shoes, thus maintaining equalization.

This device has the advantage of assuring brake operation for all other brake drums, in case one individual unit should fail.

HUDSON AND TERRAPLANE DUAL-HYDRAULIC BRAKES

Hydraulic brakes were adopted by Hudson-Terraplane in 1936. In addition to the hydraulic type of brake which may be serviced according to the instruction given for the Lockheed brakes, these cars are fitted with an interesting mechanical device designed to act on the brakes on the two rear wheels after the foot pedal has traveled a predetermined distance toward the toe board. In normal operation, the braking action is wholly one of hydraulic force. A diagram of this design is shown in Fig. 87. While the actual layout of the braking mechanism is somewhat more complicated than this, Fig. 87 does

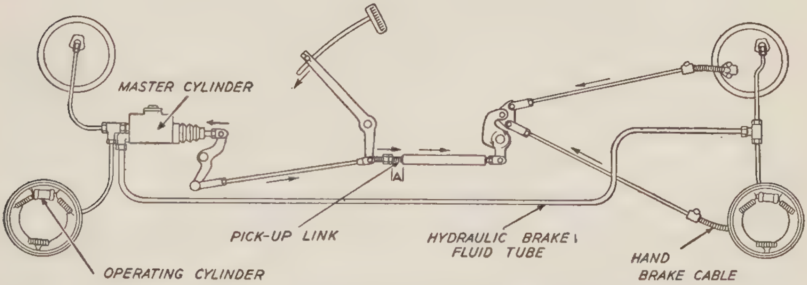


Fig. 87. Hudson-Terraplane Dual-Hydraulic Brakes with Mechanical Pick-up Link

serve to illustrate just how the mechanical hook-up works in connection with the hydraulic hook-up. The hydraulic fluid flows at all times to both the front and rear brakes from the master cylinder. The pick-up link, shown at *A*, allows a certain space to be traveled before the mechanical device comes into action. With proper amounts of fluid in the lines and brake setting made according to specification, the space *A* is not taken up in ordinary service brake usage. This mechanical hook-up serves a further usage since it is connected to the hand brake lever for parking use.

BUICK BRAKES

When making adjustments for lining wear on the Buick hydraulic brakes fitted to the 1936 cars, the drums should be at room temperature approximately. The brakes should be correctly adjusted when the pedal travels within two inches of the toe boards when the brakes are applied, or three inches for high-speed driving.

First, jack up all four wheels and remove the covers over the adjusting holes found in the brake backing plates.

Disconnect rear parking brake cables which are attached to the cross shaft, and check the foot-pedal clearance at the toe board. This pedal clearance should be ⅜ inch. Next, loosen the lock nut on the eccentric adjustment one-half turn and then rotate the eccentric in the direction of the forward motion of the wheel until a heavy drag is felt on the drum. Then rotate the eccentric very slowly in the opposite direction until the drum is free, without any brake drag. Tighten the eccentric lock nut, holding the eccentric from moving at the same time.

Inspect to see if the anchor pin nuts are tight. If the anchor pin nut is found to be loose, readjust according to the instructions given. Adjust the parking brake cable.

Expand the brake shoes by turning the adjusting screw, and move the tool toward the center of the wheel until the brake drum can just be turned by hand.

If it requires more than fifty notches on the adjusting screw to cause the heavy drag on the drum, it may indicate that the linings are worn and should, therefore, be renewed.

Back off the adjusting screw approximately 17 to 20 notches. The brake drum must then turn freely. If a heavy drag is felt between the shoes and the drum, reset the eccentric until the drum turns freely. Lubricate the brake pedal and brake connections to the master cylinder and also the brake cable clevis pin. Re-install the adjusting hole covers in backing plate.

STUDEBAKER 1936 HILL HOLDER

The Studebaker Co. has introduced and installed on their 1936 cars, a very ingenious but simple device called a hill holder. This device gives better and easier control of the car, on a hill or in traffic, where it is necessary to prevent the car from rolling back while starting the movement of the car in a forward direction. The device is connected to the clutch pedal, but it does not in any way affect the ordinary use of the brakes or clutch.

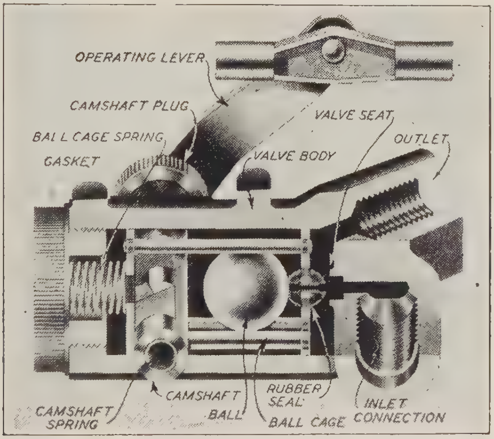


Fig. 88. Studebaker Hill Holder—"Off" Position
Courtesy of Studebaker Corporation, South Bend, Indiana

The hill holder comes into operation when the clutch pedal is operated at the same time as the brake pedal, and will hold the car stationary and prevent it from rolling backward as is the case when stopping on a hill. When the clutch pedal and brake pedal are depressed at the same time, the brakes will remain on as long as the clutch pedal is depressed, even though the brake pedal is released. This leaves the driver free to use the right foot for the accelerator pedal when starting the car moving again.

The hill holder is a simple valve which does not allow the return of the brake fluid in the lines until the clutch pedal is allowed to return to the engaged position of the clutch.

The valve is controlled both by the clutch pedal and by a ball which is allowed either to roll back and seat against a rubber seal in the back end of the ball cage, or to roll away from the rubber seal, rendering the valve inoperative regardless of the clutch pedal position. In operating at the time the brakes are applied, the fluid from the master cylinder enters the valve, and, even if the clutch pedal is depressed, the pressure of the brake fluid forces the cage assembly back against the spring, allowing the fluid to flow through to the outlet and then into the wheel cylinders. When the clutch pedal is released, or when the car is going down grade, the ball cage is in the forward position, allowing the fluid to flow through the unit without any interference. This is shown in Fig. 88.

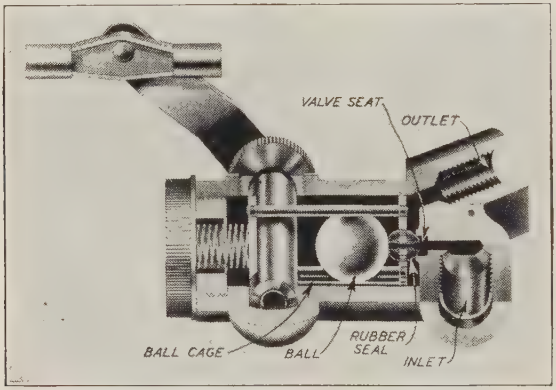


Fig. 89. Studebaker Hill Holder—"On" Position
Courtesy of Studebaker Corporation, South Bend, Indiana

When the car is on an up grade, the cage is in the rear position, with the rubber seal seated on the passage to the master cylinder and with the brake and clutch pedals depressed. The ball has also rolled back by gravity and closed the aperture in the seal. This is illustrated in Fig. 89. This prevents the fluid from going back to the master cylinder, and the brakes remain in the "on" position. With the clutch pedal in the engaged position, the valve moves ahead and permits the fluid to flow back to the master cylinder.

There are two simple adjustments, one to make sure that the bosses on the top of the hill holder are level when the car is on a level surface, and the other is the control rod which must be so adjusted that the brakes release just ahead of the engagement of the clutch.

Horsepower Required to Stop an Automobile. The horsepower chart illustrated in Fig. 90, shows the comparative relation between the horsepower developed by the engine and the horsepower developed by the brakes when stopping the car. The performance of the eight-cylinder engine is comparable to that of most automobile passenger-car engines. It is possible with the automobile to go from a standing start to eighty miles an hour in thirty-six seconds. Conversely, applying the full force of the hydraulic brakes, but four and one-half seconds are required to bring the car from eighty miles an hour to a

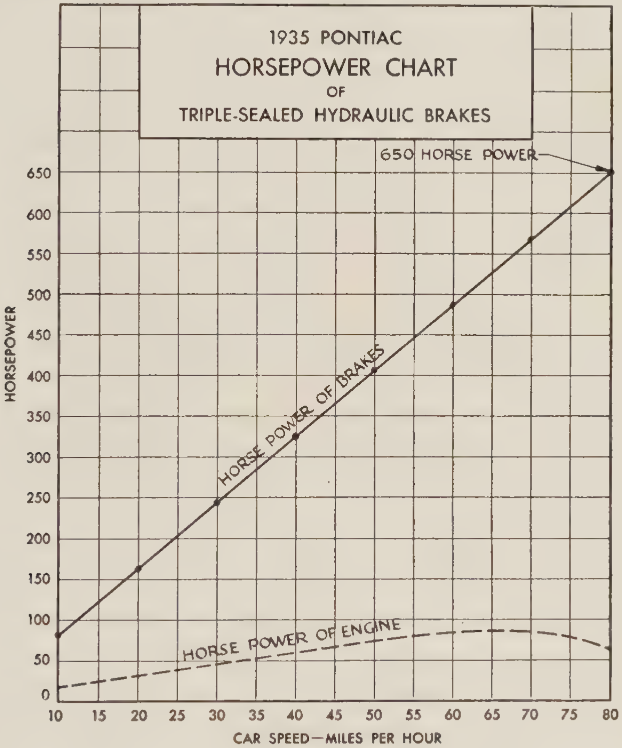


Fig. 90. Comparison of Engine and Brake Horsepower

stop. The time required to make the stop is one-eighth as long as that required to accelerate to eighty miles an hour.

By the same line of reasoning, if it requires the expenditure of eighty horsepower to bring the car to eighty miles an hour in thirty-six seconds, and but four and one-half seconds are required to absorb all of the energy stored in the car and bring it to a stop, then the brakes have actually delivered within this four and one-half second interval, 650 horsepower, which has been expended in the friction between the brake linings and the drum surfaces in doing the work of actually stopping the automobile.

DIESELS FOR TRANSPORTATION

PART I

The Diesel has been adapted to almost every use for which other engines have been employed. They are used in central power stations, industrial apparatus, ships, launches, trains, tractors, motor vehicles, and even airplanes. Figs. 1, 2, and 3 illustrate modern Diesel engine building practice.

Economy of fuel is accomplished by the Diesel through the use of high internal pressures, and it has proven conclusively its ability to produce a given amount of power with a lesser quantity of fuel than any other heat engine now known.

While the steam engine, under ideal conditions, may reach an efficiency of twenty per cent, and the gasoline engine when conditions are perfect attains twenty-five per cent efficiency, the Diesel under ordinary conditions, and through all sizes of power plants, shows efficiencies of from thirty to thirty-six per cent. Efficiency means the percentage of heat in the fuel delivered as power at the flywheel to do useful work.

The Diesel principle is not new. Dr. Rudolph Diesel began his experiments in 1893 in the M.A.N. shops in Germany. The first engine was designed to burn powdered coal. Almost every imaginable fuel has been used, including gasoline, kerosene, alcohol, distillates, furnace oil, crude oil, and even fish oil.

The original Diesels were extremely heavy, weighing several hundred pounds per horsepower. It has been only in recent years that the modern engineer and metallurgist have combined low weight with its great economy and reliability to make its application almost universal. Part of this lessening of weight comes from an increase in speed. Diesels may now be had in speed ranges from one hundred fifty to over two thousand revolutions per minute.

This explanation of Diesel principles and methods is not intended as an engineering treatise, but rather it is an endeavor to make plain to the man who is meeting up with Diesels, the "hows" and "whys" of their operation. It is impossible for one to understand the Diesel principle without some knowledge of the functions involved in the operation of the internal-combustion engine.

England seems to be the birthplace of the scientists who discovered laws of physics upon which all principles of heat engines are based. Boyle, 1662, and Charles, 1790, developed that the volume, or pressure, of a gas varies in proportion to its absolute temperature; and inversely, the temperature of a gas varies as its pressure, or volume. Joule, about 1870, established that heat resulting from the compression of gases is absolutely not caused by friction between molecules.

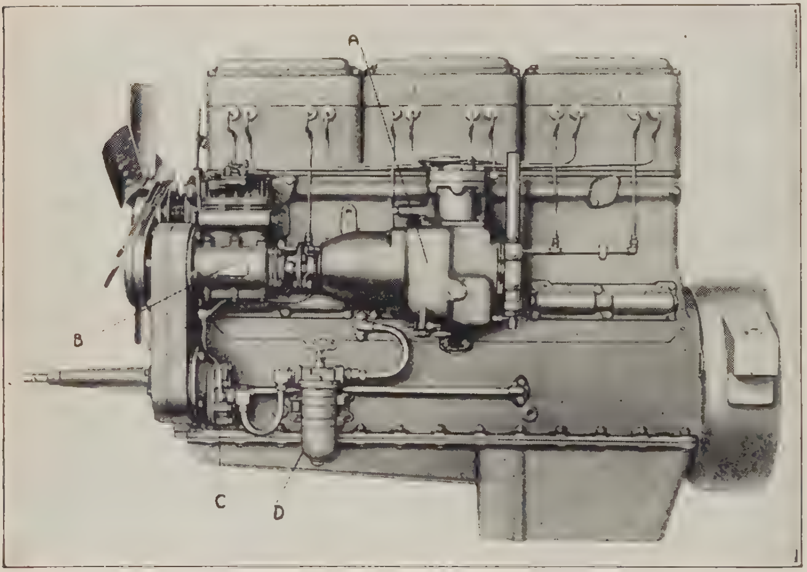


Fig. 1. Injection Side of Cummins Bus Type Diesel Engine
A—Distribution Type Fuel Injection System; B—A Compressor for Brakes;
C and D—Lubricating Oil Pump and Filter (Refer to Fig. 6)

If you take a cylinder, fitted with an air-tight piston, the space in the cylinder being filled with air at atmospheric pressure, and heat that air, the air will expand, causing the piston to move outward. This is done in a gasoline engine by burning fuel in a cylinder crammed full of air. The burning fuel heats the air, causing a high pressure against the piston, which delivers the resulting pressure through the connecting rod to the crankshaft to do work. If the piston is forced into the cylinder, then the pressure is increased and the temperature of the air is increased also. If the pressure is increased sufficiently, the temperature will become high enough to set fire to a mixture of fuel and air. This often happens in automobiles when an accumulation of carbon decreases the compression space, causing such high pressures that the mixture fires before the spark occurs, causing a knock.

Diesel engines utilize these phenomena to operate the Diesel cycle. Diesel engines are now known as those engines in which fuel, injected after compression is practically completed, is ignited solely by heat resulting from the compressing of air supplied for combustion. The Diesel action is as follows: Pure air, which is not combustible, is compressed at three hundred seventy-five to five hundred pounds per square inch, raising the temperature of that air to from five hundred to one thousand degrees Fahrenheit—sufficient to ignite almost any fuel instantly. Just before the completion of the compression stroke, a measured quantity of fuel is injected into the cylinder where it burns, heating the air to a greatly increased temperature. The resulting pressure is transmitted by the piston and connecting rod to the crankshaft to do work.

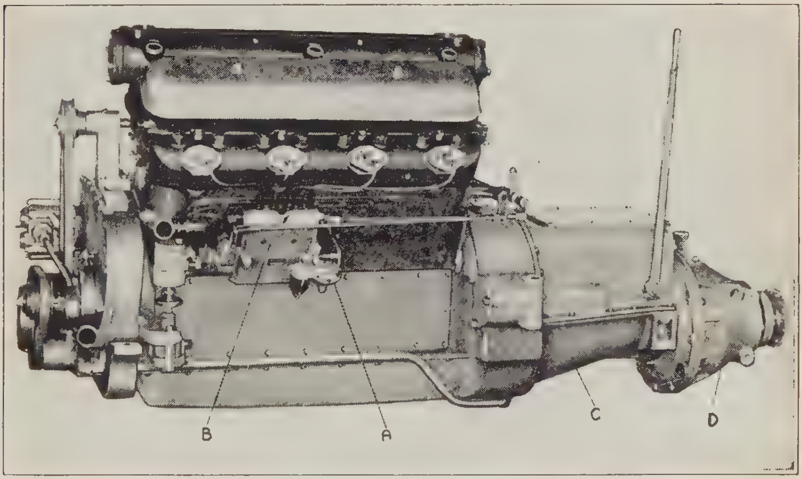


Fig. 2. Hill V-8 Type Diesel Eight-Cylinder Engine 5″ x 7″ 200 Hp. at 1600 r.p.m.
A—Fuel Pump; B—Injection Pump for Right Bank
(See Figs. 7 and 8) C—Marine Reverse Gear; D—Reduction Gear
Courtesy Hill Diesel Engine Company, Lansing, Michigan

In the Diesel cycle the fuel is injected into the combustion chamber until about ten per cent of the power stroke is completed. As the piston moves away from the cylinder head, the pressure seldom rises materially above that of compression. The rest of the stroke is used for expansion of the heated gases. This comparatively steady pressure over the top of the stroke gives rise to the name "constant pressure" as applied to the Diesel. Other engines, using lower compression pressures, complete combustion at about top center, devoting nearly all of the power stroke to expansion. These are called "constant volume" engines.

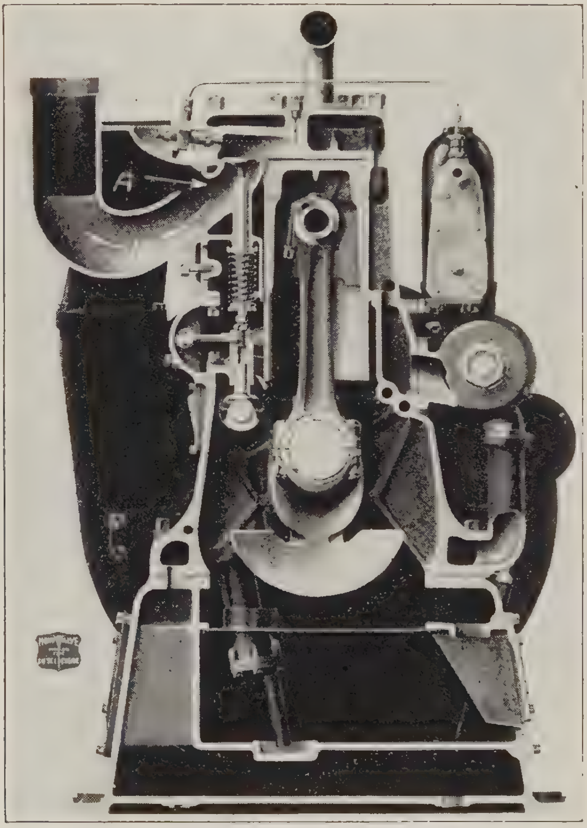


Fig. 3. Monovalve Diesel Engine
Air is supplied by a blower, built in the flywheel, entering the valve through passage A; Exhaust leaves through B which forms a venturi throat.
Courtesy of American Diesel Engine Company, Oakland, California

Diesel engines may be classified under the following headings: Two-stroke or four-stroke cycle; single or double acting; air or solid injection; direct injection or pre-combustion; and common-rail or individual pumps. For example, a certain automotive Diesel might be described as four-stroke cycle, single acting, solid injection, pre-combustion, individual pump type, followed by the usual description as to bore and stroke, revolutions per minute, etc.

Four-Stroke Cycle. The diagrams, Figs. 4 to 7, show for comparison the operations in the most generally known gasoline engine and in a Diesel of the same type. In the suction operation, Fig. 4, the gasoline engine draws in a charge of fuel and air, while the Diesel takes in pure air only. During the compression operation, Fig. 5, the gasoline engine compresses the fuel-air mixture to about one hundred pounds per square inch, while the Diesel compresses air to about five hundred pounds per square inch, and a temperature of approximately one thousand degrees Fahrenheit. On power stroke, Fig. 6, the gasoline-air mixture (ignited by spark) burns at top center, while in Diesel, the fuel injected ignites from com-

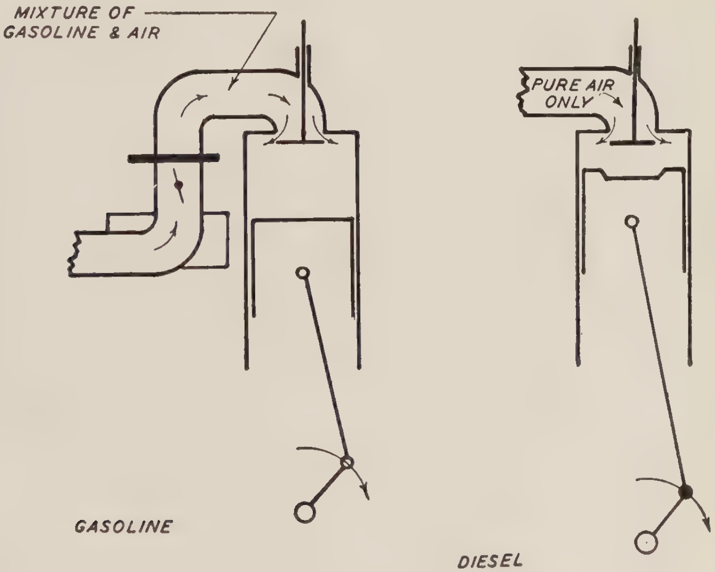


Fig. 4. Diagram Showing Suction Stroke

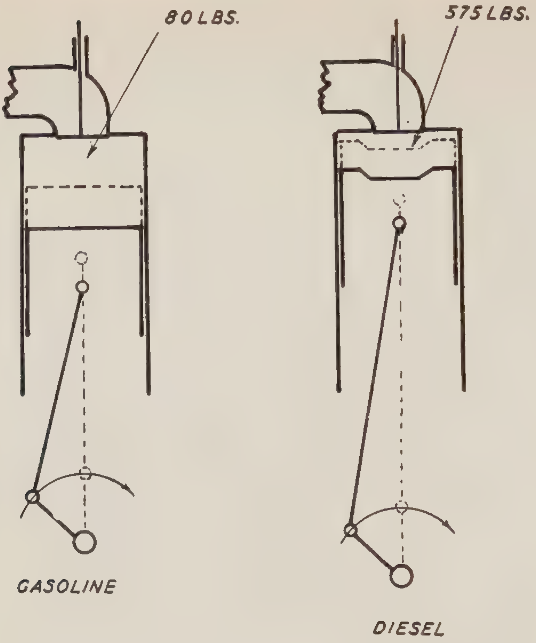


Fig. 5. Diagram Showing Compression Stroke

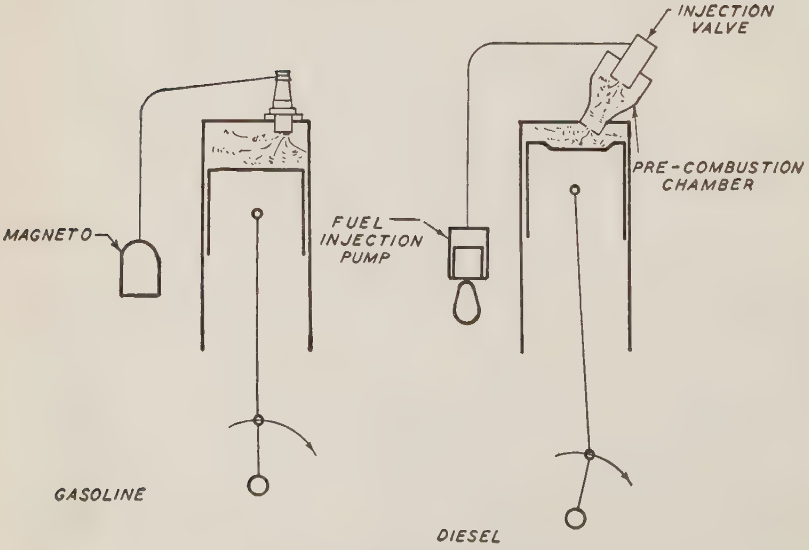


Fig. 6. Diagram Showing Power Stroke

pression heat and injection continues after top center. On exhaust stroke, Fig. 7, exhaust gases leave the gasoline engine at twelve to fourteen hundred degrees Fahrenheit, whereas in Diesels exhaust gases leave at six to nine hundred degrees Fahrenheit.

Thus it is apparent that in the Diesel explosion pressures are materially lower, since the fuel is burned over a longer period of time; and that since exhaust temperatures are lower, combustion must be more complete.

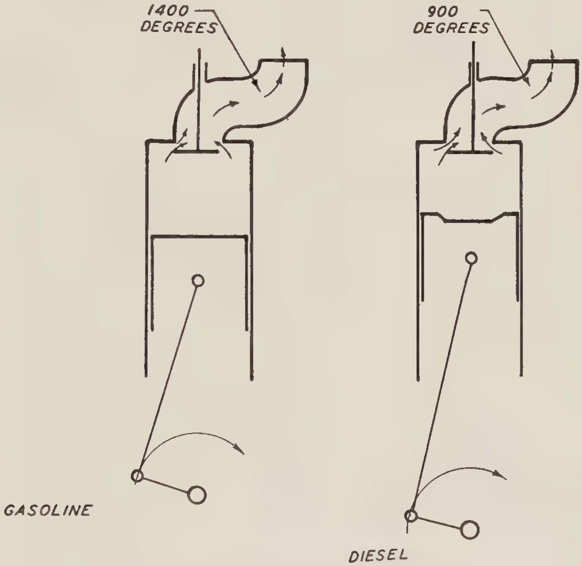


Fig. 7. Diagram Showing Exhaust Stroke

Two-Stroke Cycle. In this Diesel engine all work is completed in two strokes of the piston, Fig. 8. Injection occurs at the upper end of the compression stroke, as in the four-stroke engine, continuing through a portion of the power stroke. Near the end of the power stroke, the piston uncovers a port, open to the atmosphere, allowing spent gases to escape. After the piston has about half uncovered the exhaust port, it uncovers the inlet port on the opposite side of the cylinder, through which air from a scavenging pump passes to force the remaining exhaust gases out of the exhaust port, leaving the cylinder full of clean air for a new compression stroke.

Two-stroke cycle Diesel engines must have a supply of air under low pressure to blow out the exhaust gases and refill the cylinder with clean air. The simplest way to do this is to compress this air on the under-side of the piston, in the crankcase. In multi-cylinder engines this involves many check valves and considerable effort to insulate each crankcase from the other, so some makers use a very large double-acting piston pump at one end of the crankcase to do this work. This system makes a larger quantity of air available and is very satisfactory. Others have used vane pumps and Rootes blowers, while aircraft engines use centrifugal blowers because of their compactness and light weight.

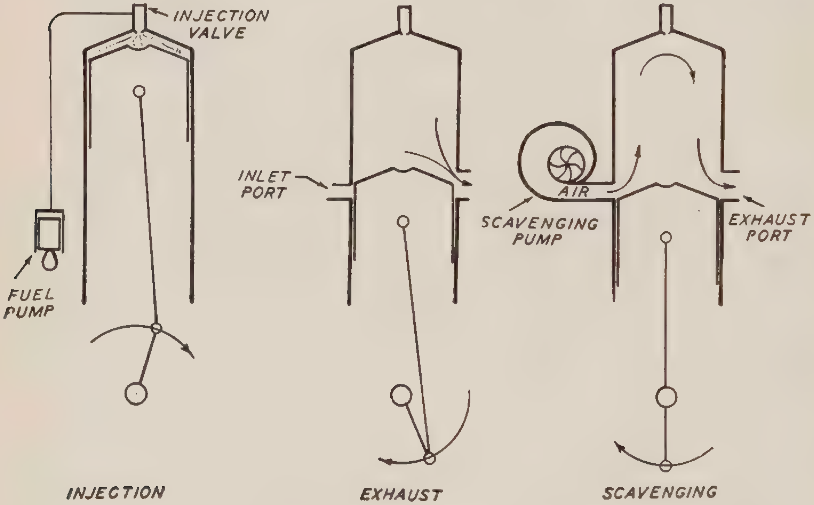


Fig. 8. Diagram Showing Two-Stroke Cycle Diesel

Single-Acting Diesel Engines. Conventional engines are single-acting, doing work on but one side of the piston. They range from five to one thousand horsepower per cylinder, either two-stroke or four-stroke cycle.

Double-Acting Diesel Engines. Double-acting engines have a combustion chamber on each side of the piston and use a cross-head something like a steam engine. Pistons are water-cooled. The power range is from three hundred to two thousand horsepower per cylinder, usually two-stroke cycle.

Air Injection. Dr. Diesel built his original engine to burn powdered coal, although his original patent covered the use of liquid fuels. By this system of air injection, fuel is metered to an injection valve, Fig. 9, at a relatively low pressure, whence it is blown into the combustion chamber by an air blast with a pressure of upward of fifteen hundred pounds per square inch. The air injection pumps consume from five to fifteen per cent of the total engine power.

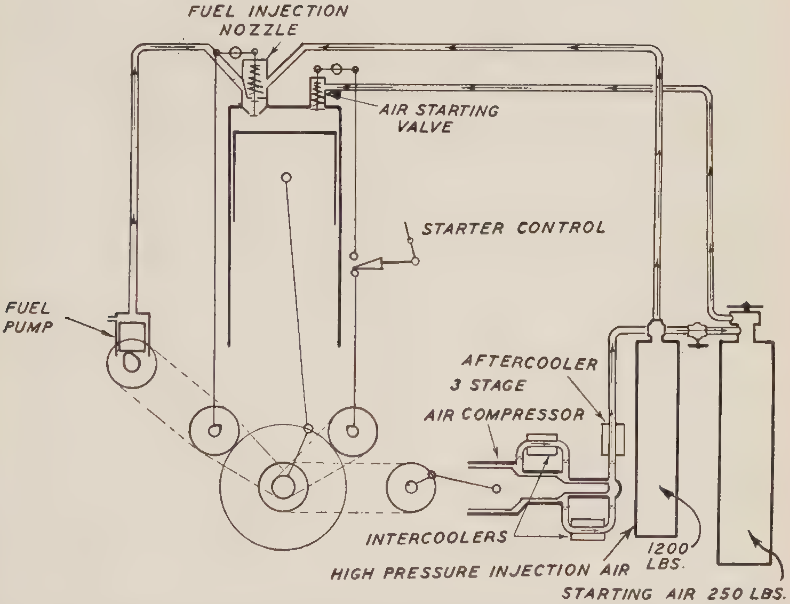


Fig. 9. Diagram Showing Inter- and After-Coolers Required to Cool the High-Pressure Injection Air before It Reaches the High Pressure Tank, Also Method of Placing Starter Valve in Operation

Solid Injection. By this method of solid injection, the fuel is injected directly into the cylinder, or into a chamber open to the cylinder.

Direct Injection. Here the fuel is injected directly into the cylinder. This may be either by the air or solid (airless) injection method, Fig. 10.

Pre-Combustion. "Divided" or "twin" combustion are names also used by various makers to describe this method of burning the fuel. A sort of ante-chamber, which is open to the cylinder, Fig. 9, through a bottle-neck, receives the fuel from the injection valve.

There the fuel partly burns, the resulting pressure forcing the remainder out into the cylinder where combustion is completed. This is a very satisfactory method, especially for cylinders of six-inch bore or less.

Common=Rail. Here a single pump maintains a fuel pressure of three to five thousand pounds per square inch in a "rail" or pipe, which is common to the several injection valves, Fig. 11. Cams and rocker arms control the opening and closing time of the injection valves. Speed and power are controlled by regulating the fuel pressure or varying the lift of the injection valves.

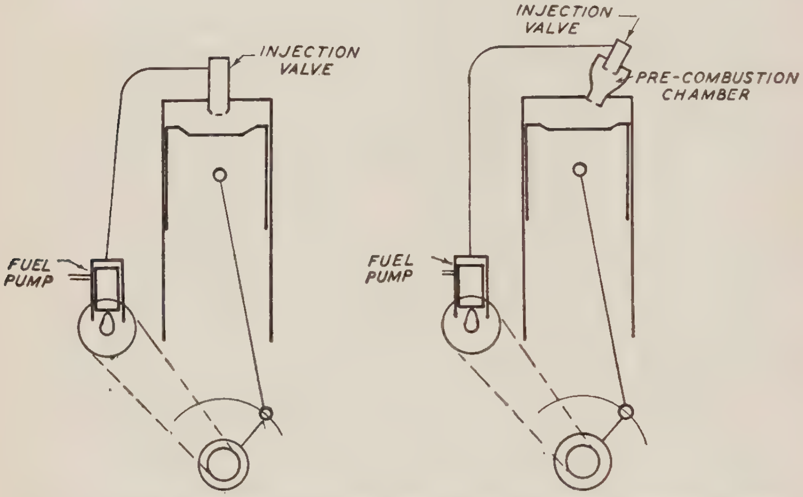


Fig. 10. Diagram Showing Direct Type and Pre-Combustion Chamber Type Solid Injection

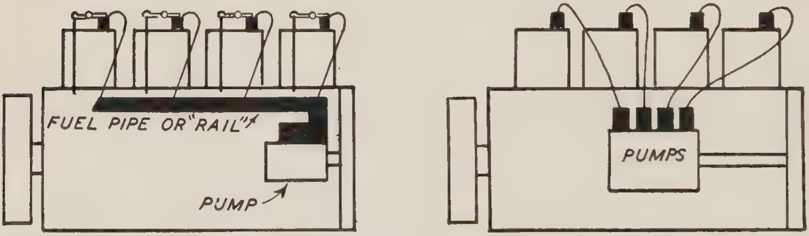


Fig. 11. Diagram at Left Shows a Common Rail Type Pump and at Right an Individual Pump Type

Individual Pump. This individual pump method for fuel injection provides separate pumps for each cylinder. They meter the correct quantity of fuel and apply a pressure of fifteen hundred to three thousand pounds per square inch to force the fuel through the injection valves into the combustion chamber, Figs. 11 and 13. Speed and power are controlled by a by-passing arrangement or by varying the lift of the pumps.

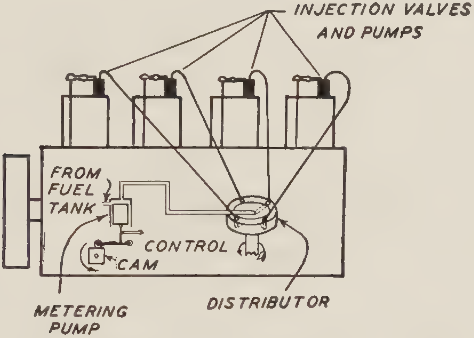


Fig. 12. Diagram Showing a Distributor Type Pump

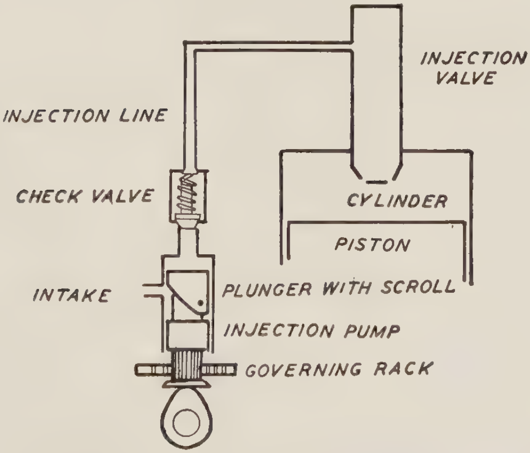


Fig. 13. Diagram Showing an Individual Fuel Pump with By-Pass Control

Distributor System. The distributor system for fuel injection is a variation of the individual pump method. A single metering pump measures the fuel charge for all cylinders, Fig. 12, and forces it through a distributor to the proper cylinder, where a combination pump and injection valve injects the fuel into the cylinder.

Injection Valves. The most generally used injection valves are of the spring-loaded relief valve type, of needle design. These are used with the individual pumps. The valve, Fig. 14, is lifted by the pressure from the pump. Powerful springs seat the valves, their pressure helping to atomize the fuel and time the injection.

Spray Nozzles. The spray nozzles are the part of the injection valve, Fig. 14, through which the fuel passes when entering the combustion chamber. The purpose is to atomize the fuel and to direct the spray in such manner that combustion is best effected.

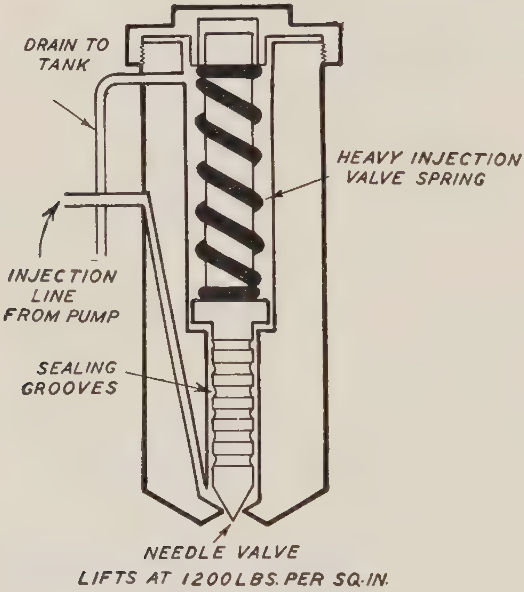


Fig. 14. Diagram Showing a Typical Fuel Injection Valve

Pressure Relief Valves. In many Diesels a safety valve, Fig. 15, is located in the cylinder head. It pops off when pressures greatly exceed normal combustion pressure. This condition may occur if the engine is given a too open throttle before operating speed is attained.

After Chambers. As an aid to combustion, a chamber apart from but open to the cylinder is used by some makers. Here air is compressed with the main charge, to pass back into the cylinder as combustion pressure falls, Fig. 16, thus giving turbulence with additional clean air for burning the fuel. These after chambers are found either in the cylinder head or piston. Where an after chamber is connected to the cylinder head and low compression pressure is used, a valve may be used to cut the after chamber off from the

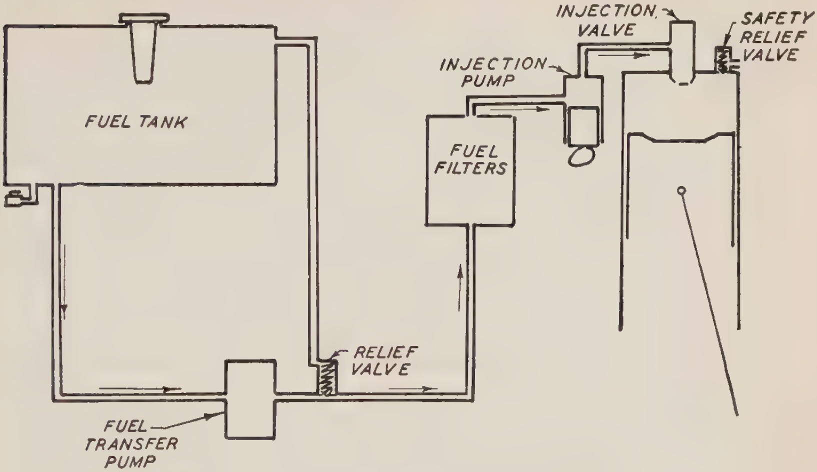


Fig. 15. Diagram Showing a Typical Diesel Fuel System

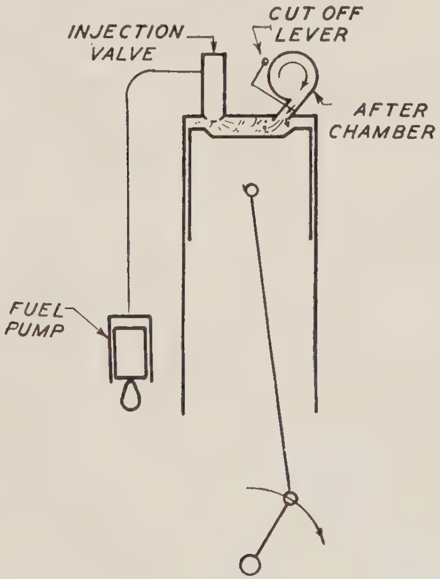


Fig. 16. Diagram Showing an After-Chamber Type Solid Injection Valve

cylinder, thereby raising the compression pressure for starting purposes.

Compression Ratios. Diesel compression ratios vary from twelve to twenty to one, according to the maker and purpose. It is general practice to use the lowest ratio at which the fuel will burn satisfactorily, thus cutting down on power loss due to compressing air and also to lighten the structure. Some fuels will not burn under the lower pressures, and too low a ratio leaves little margin to cover compression losses caused by valve or piston ring leakage. Automotive and industrial Diesels operating at high altitudes require higher compression ratios to compensate for lowered atmospheric pressure.

Compression Pressures. Combustion chamber size and shape have a great effect upon compression pressure and temperature. For a given ratio, a small cylinder has a greater combustion wall area for its displacement than a large one. This means a proportionately greater loss of compression heat to the cooling system, and a consequently lower actual compression pressure in the small cylinder. Small Diesels demand a higher compression ratio to insure satisfactory operation under cold conditions, high altitudes, and when using fuels with a high ignition point. Glow plugs, insulated precombustion chambers, and valves for cutting off after chambers are methods used to overcome low compression difficulties.

Glow Plugs. Diesels of the lower compression ratios may not fire the fuel at cranking speeds when cold, although once the engine has started, residual heat in the combustion chamber raises the air temperature high enough to insure ignition. Some manufacturers place a glow plug in the cylinder. This plug is heated by a battery, only while the engine is being started, to provide the additional temperature needed to start combustion.

Fuel System. Parts comprising the fuel supply system for Diesels are: Fuel tank, fuel transfer (supply) pump, relief valve, and filter, Fig. 15. The purpose is to supply clean fuel to the injection pumps at the proper pressure to insure good operation. It is imperative that all water, dirt, and air be excluded from the system. Dirt or grit is fatal to the pumps as they are constructed with clearances as small as one-fourth of one ten-thousandth of an inch, Fig. 13, while the spray nozzle orifices may be as small as five one-thousandths of an inch in diameter. Water rusts, thus irreparably damaging delicate and expensive parts; and even the smallest quantity of air may render the injection system inoperative.

Fuel Charge. A Diesel cylinder, 5¼ inches by 8 inches, operating at full power, receives less than one one-hundredth of a cubic inch of fuel at each injection; and at idling, less than one-fourth of that. The average thin pencil lead 1¼ inches long equals about one-hundredth of a cubic inch. Smaller engines inject proportionate amounts.

Starting Systems. Due to the high compression pressures, only the very smallest Diesel engines can be started by hand. The large ones use compressed air starters, Fig. 9, while the smaller high speed types use electric starters, operated by batteries of from twelve to thirty-two volts. A large builder of tractor and industrial Diesels uses a small hand-started gasoline engine to engage the Diesel flywheel in the automotive manner, thus eliminating all air compressors and batteries.

Fuels. While their specifications are not critical, Diesel fuels must meet certain specifications, especially for the protection of the injection system and other engine parts with which the fuels come into contact. The chief requirements are that the fuels flow freely at any temperature in which the engine may have to operate; that they contain the necessary lubricating properties to protect the injection apparatus; that they are free of gritty matter and contain no injurious quantity of corrosive acids; and that they have a minimum quantity of carbon residue and a low enough ignition point to catch fire readily under the heat of compression.

Kerosene and other light fuels may be used if about five per cent of engine oil is added to lubricate the pumps. Crankcase drainings must not be used as the grit contained will ruin the expensive injection apparatus, while the carbon will foul the spray nozzles and cylinder walls. Nothing is to be gained by using light fuels, because Diesel economy is partly due to the ability to burn the very cheapest of commercial fuels.

Ignition Point. This is the lowest degree of temperature at which the fuel will ignite (catch fire).

Flash Point. This is the lowest degree of temperature at which the fuel gives off vapors in sufficient quantity to ignite momentarily (flash) when exposed to a naked flame. A low flash point indicates good vaporizing qualities. This difference should be noted. Many fuels, such as alcohol, benzol, and high octane gasoline have such a low flash point as to be very dangerous if kept in the proximity of an open flame, yet possess an ignition point too high for practical use in Diesels.

Lubrication. The circulation pressure oiling system is universally used and oils of somewhat higher viscosity than automobiles require are the rule. Filters are provided in all cases to guarantee clean oil, thereby preserving the perfect cylinder wall and piston ring surfaces so vital to good compression and long life.

DIESELS FOR TRANSPORTATION

PART II

HERCULES "DHX" FOUR-STROKE DIESEL CYCLE ENGINE

PRINCIPLES OF OPERATION

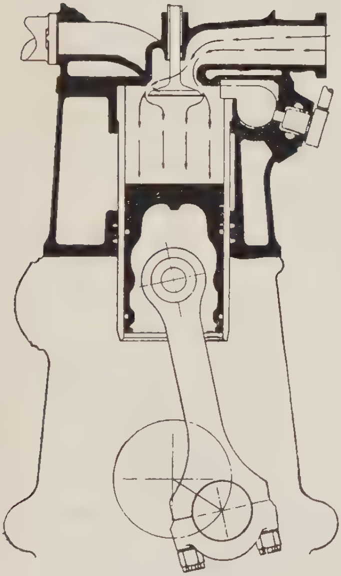


Fig. 17. Intake Stroke

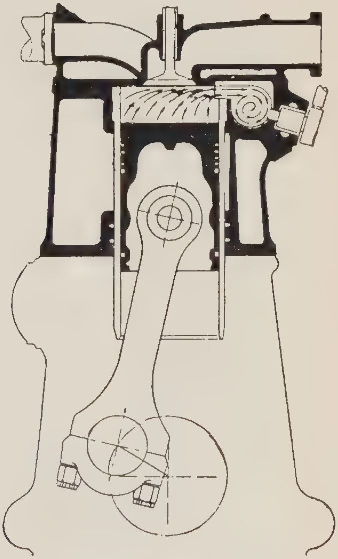


Fig. 18. Compression Stroke

There are both two- and four-stroke-cycle gasoline and compression-ignition engines. There are also two- and four-stroke-cycle air-injection and solid or mechanical-injection compression-ignition engines. As the Hercules DHX series engine is one of the more popular four-stroke-cycle solid or mechanical-injection engines, it is described here. The functions of the different strokes are shown in Figs. 17 to 21, which show the various strokes of the Hercules Diesel

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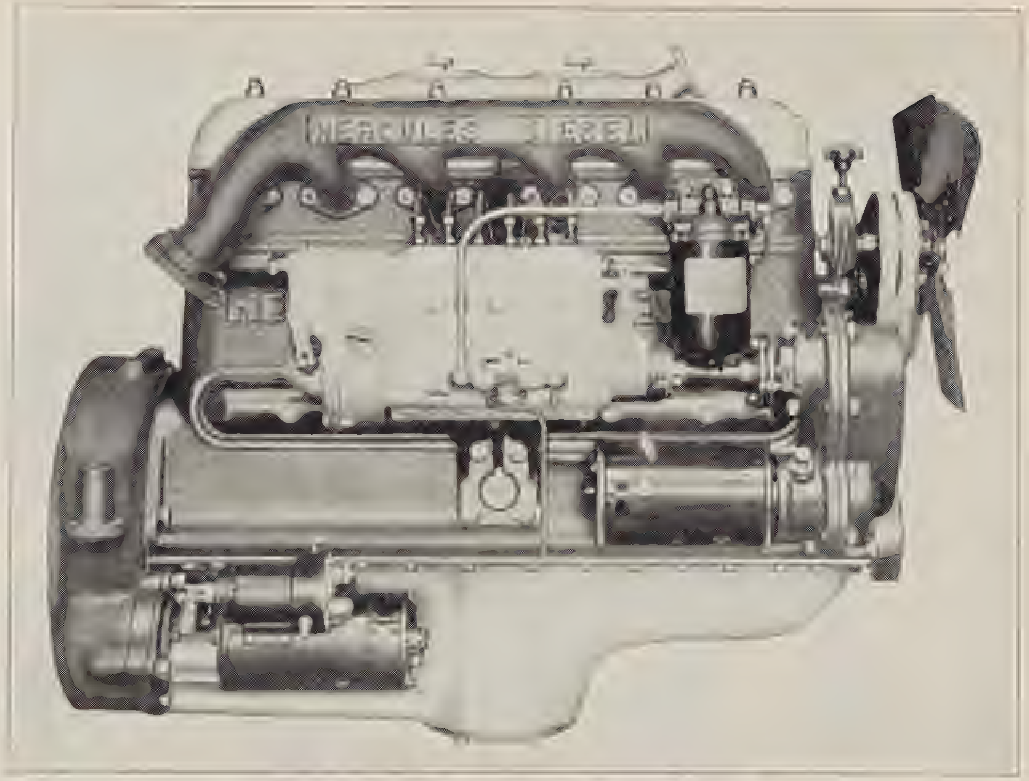
Note.—The design and service information contained in this section is made available through the courtesy of the Hercules Motors Corporation of Canton, Ohio.



FUEL PUMP SIDE OF HERCULES DIESEL ENGINE
(Courtesy Hercules Motors Corporation, Canton, Ohio)

cycle-type engine. No carburetor is attached to the intake manifold.

Intake Stroke. The air intake valve, Fig. 17, is opened by the rocker arm actuated by a cam through tappets and rods. Pure clean air is drawn through this valve into the cylinder as the piston travels downward.

Compression Stroke. The intake valve has closed and the exhaust valve, Fig. 18, remains closed so all air taken into the cylinder on the intake stroke is now being compressed between the cylinder head and the piston. However, on one side of the Hercules cylinder there is an opening to a spherical shaped combustion chamber. The air rushes through this opening into the combustion chamber as shown by the arrows, and due to the shape of this chamber is set into a whirling motion. This compression of the air is heating it to temperatures higher than the ignition point of the fuel soon to be injected.

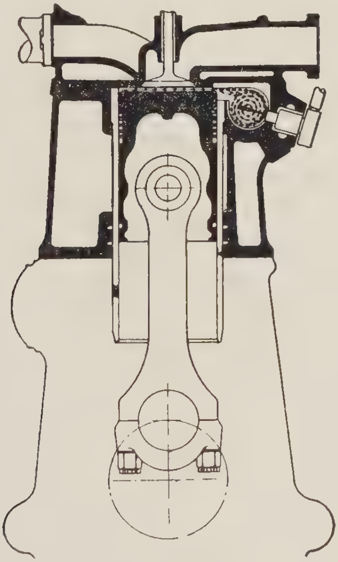


Fig. 19. Fuel Injection

Fuel Injection. This is not a stroke, Fig. 19, but is approximately the end of the compression stroke and the beginning of the expansion. The fuel begins to inject at approximately 18 degrees before top center and continues until approximately 14 degrees past top center, when the engine is carrying full load at a speed of 1300 r.p.m. This injection is controlled by the fuel-pump timing, the nozzle-pressure setting, and the load on the engine operating the governor which in turn controls the length of time the pump will continue injection. This will be described under "Hercules Type Governor."

Turbulence of air in the combustion chamber is of greatest importance just as the fuel is injected. This insures all of the fuel coming in contact with all of the air, and this thorough mixing results in complete combustion or burning. Heretofore this has been a problem in all compression ignition-injection engines, as no matter what design was used in shaping the heads or combustion chambers, the air velocity would slow up and usually stop just when the fuel was being injected. This would cause high fuel consumption without maximum power, and was accompanied by a smoky exhaust and noisy combustion. This reduced turbulence was due to the piston slowing down as it approached top center. At the exact point of top center, the piston has no speed or motion, because this is the exact point of reversal of direction.

The air velocity is dependent on the speed of the piston and the size of the opening through which this air must pass. The larger the opening, the slower the velocity of air passing through it; the smaller the opening, the greater the velocity for the same amount of air to pass through in the same length of time. An example similar to this is water passing through a garden hose and nozzle. If the nozzle is wide open and there are no obstructions, the water passes through with only the velocity of its pressure. If the nozzle is nearly closed, the water comes out with much greater velocity, even though there has been no increase of the pressure.

Hercules engineers solved this problem of turbulence by locating the combustion-chamber opening on the side of the cylinder. As the piston travels upward from bottom center, the air velocity is steadily raised due to the piston speed. The air passing into this chamber is set whirling, as explained under compression stroke. However, when this air velocity would tend to slow up due to reducing piston speed, the piston begins to cover the chamber opening, so that the velocity is steadily increased until the piston is about 12 degrees ahead of top center. By then, however, the velocity of air is not important as injection has taken place, beginning at approximately 18 degrees before top center, and ignition takes place at about 10 degrees before top center. The air revolves inside the combustion chamber forty-three times the crank-shaft speed at the time injection begins, and increases to fifty times crank-shaft speed during ignition and combustion. The injection of the finely atomized fuel mist into this rapidly moving air, insures a complete mixing of air and fuel. This results in more complete combustion, therefore maximum power with minimum fuel consumption, smoke and noise. The uniform burning also results in smooth, even power.

While the piston is traveling from approximately 18 degrees before top center to about 10 degrees before top center, the fine fuel mist is mixing with the whirling, hot, compressed air in the combustion chamber. At approximately 10 degrees before top center this air is so high in temperature that the fuel mist ignites and burns. Injection continues until the piston is approximately 14 degrees past top center, and at 20 degrees past top center, combustion is completed and expansion takes place.

Expansion or Power Stroke. The rapid rise in temperature of gases due to burning of the oil, causes them to expand as shown in Fig. 20. As the only movable part in the cylinder is the piston, these expanding gases push it downward. This downward force is transmitted to the crank shaft (through the piston pin, connecting rod, and connecting-rod bearing) where it is converted to rotary motion and useful work.

Exhaust Stroke. The exhaust valve, Fig. 21, is now opened by its rocker arm which is actuated by its cam through tappets and push rods, and the exhaust gases are expelled the same as in a gasoline engine. The intake valve opens about the time the piston reaches top center and a similar cycle is begun.

GENERAL SPECIFICATIONS HERCULES "DHXB" ENGINE

Number cylinders	6
Bore and stroke	5x6
Displacement, cubic inches	707
N.A.C.C. Horsepower—corresponding size gas engine	60
Actual Horsepower—see power curve, Fig. 22	
Maximum recommended full load speed —see power curve, Fig. 22	

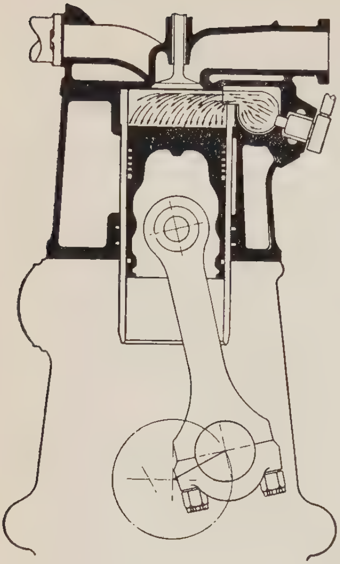


Fig. 20. Power Stroke

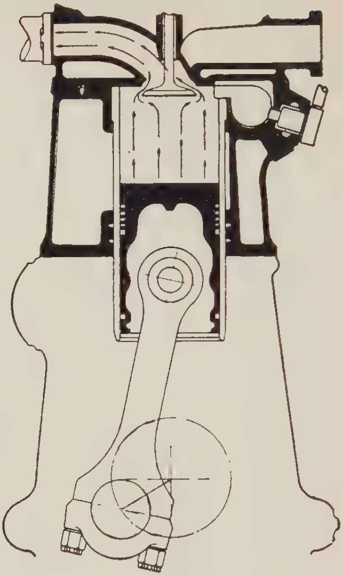


Fig. 21. Exhaust Stroke

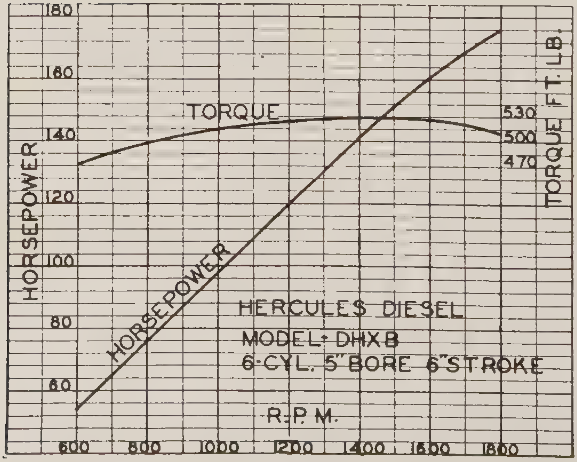


Fig. 22. Power Curve

CLEARANCES, DHX SERIES

Bearing Clearances

	Min.	Max.
Cam bearing clearance	.003	.0035
Connecting rod clearance in bearing	.0025	.003
Crank shaft bearing clearance—aluminum crank case	.004	.0045
Crank shaft bearing clearance—iron crank case	.0035	.004
Fuel pump drive shaft	.0025	.003
Idler bearing clearance	.001	.002
Oil pump-shaft bearing clearance	.0015	.002
Rocker arm bushing clearance	.001	.0015
Piston pin clearance in rod bushing	.0015	.002
Water pump shaft clearance	.0015	.002
Water pump drive shaft clearance	.0015	.0025

End Thrust

Cam shaft end thrust	.005	.008
Connecting rod side clearance	.005	.012
Crank shaft thrust clearance	.003	.004
Fuel pump drive shaft end thrust	.002	.004
Idler shaft end thrust	.003	.008
Oil pump shaft end thrust	.002	.003

Backlash

Crank shaft gear backlash to cam shaft gear	.001	.002
Generator backlash	.003	
Idler gear backlash to crank shaft gear	.001	.002
Oil pump gear backlash	.008	.010
Timing chain, measured on O.D. of coupling	$\frac{1}{64}$	
Water pump gear backlash to idler gear	.002	.004

Piston

Piston clearance to cylinder liners	.008	
Piston clearance to cylinder head	.085	.125
Piston pin clearance in piston (push fit)	.0000	.0005
Piston ring gap, oil and compression	.018	.022
Piston ring land clearance	.002	.0025

Valves

Valve guide clearance around stems, exhaust and intake	.0025	.003
Valve head below cylinder head, intake	.030	
Valve head below cylinder head, exhaust	.050	
Valve seat exhaust $1\frac{15}{16}$ inches—face of seat $\frac{13}{64}$ inch wide		
Valve seat intake $2\frac{21}{32}$ inches—face of seat $\frac{13}{64}$ inch wide		
Valve tappet clearance in bracket	.001	.0015
Tappet and valve stem clearance, exhaust hot	.016	
Tappet and valve stem clearance, intake hot	.0010	

Valve timing (see Fig. 23).

CONSTRUCTIONAL FEATURES OF THE HERCULES DIESEL ENGINE

Figs. 24 and 25 are sectioned views of a Hercules Diesel engine. A study of these two views will show that there is great similarity between the Diesel engine and the usual passenger car, truck or bus motors. However, there are certain features which are of special note. Formerly, of course, Diesel engines were considered as having no place in transportation, but belonging in the heavy-duty field, particularly in the field of stationary power. Gradually the inherent advantages of the Diesel has forced this design into the forefront until, at present, it has a wide use in transportation fields of all kinds.

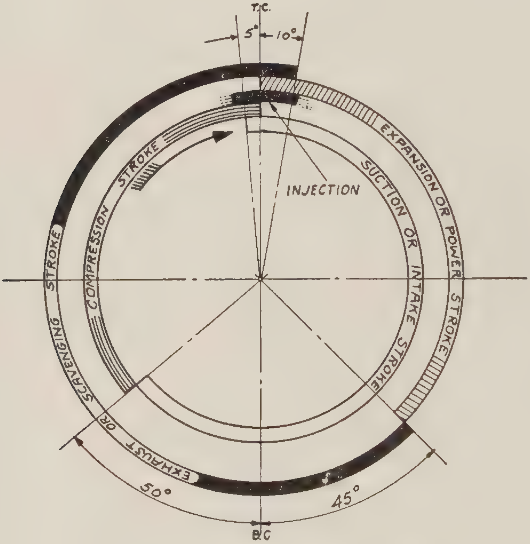


Fig. 23. Hercules Diesel Timing Chart

One of the first sections of the transportation field the Diesel engines took over, was that of power for large boats. Later they were put to use on smaller boats, and experiments with their use as power for rail cars have continued over a period of years. In some instances the rail cars made use of the oil engine in connection with electric generation and transmission.

More recently the relatively light-weight, high-speed Diesel engine has found a place for itself in trucks, buses, and tractors. The Hercules Diesel engines discussed here are of the relatively light-weight, high-speed type, although the construction of the engine is such as to care for the very much greater or heavier strains set up in the engine where high-compression pressures are used, as is the case in all Diesel engines. The preliminary discussion of the principle of the Hercules engine has brought out these facts. The student mechanic will be interested in learning just where the heavier stresses occur within the engine, and how the engine is designed to support these stresses. As mentioned previously, a study of the sectioned views, Figs. 24 and 25 will show many points of similarity. For instance, overhead valves are used, the crank shaft is seven-bearing, the oil distributing system bears quite a marked relation to other automotive engines. Pistons, connecting rods, etc., show a marked relation to good gasoline engine design. It will be noted that the cylinder and crank-case castings are relatively heavy, and in order to insure proper assembly of these parts and stiffness of the assembly, a special type of through bolt construction is used. This results in the main bearing caps, crank case, cylinder block, and cylinder head all being

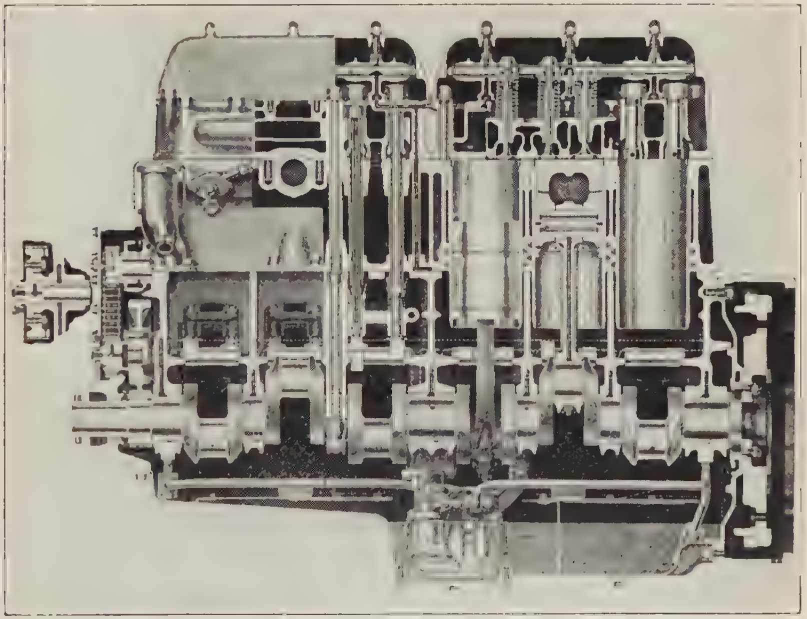


Fig. 24. Sectioned View of Hercules Diesel Engine

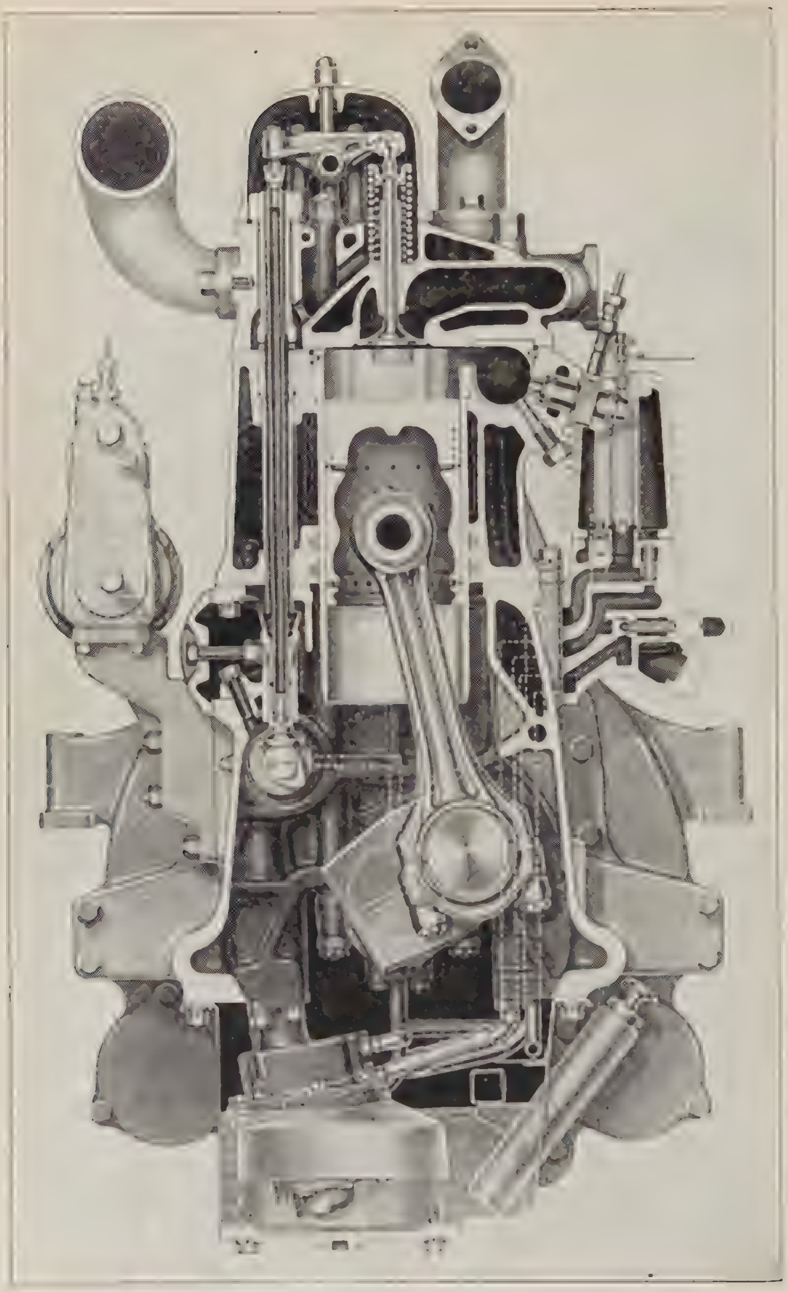


Fig. 25. Transverse Sectioned View of Hercules Diesel Engine

bolted into one structure by means of long alloy steel bolts. Each alloy stud or bolt has an eccentric head or center portion which is seated in a corresponding hole in the top of the crank case. This eccentric portion prevents turning of the stud when being tightened. This construction places all of the cast members under compression, being thus held by the tension on the alloy steel parts.

Seven main bearings are of the removable steel-back shell type, the bearing metal being of high lead-bronze construction to stand the pressures which are much higher than those commonly borne by babbitt bearings.

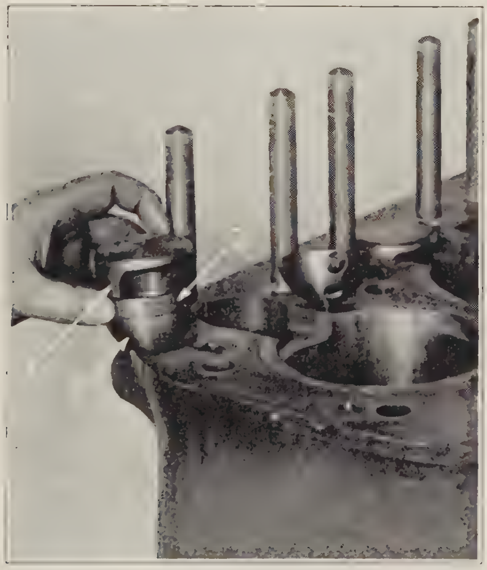


Fig. 26. Spherical Combustion Chamber with Three Liners

Combustion Chamber. The spherical shaped combustion chamber illustrated in Fig. 26, is machined in the top of the cylinder block on the water-pump side of the engine. This combustion chamber together with the three liners, are distinctly different from gasoline-engine construction. The bottom liners, marked *3*, consist of one-half of a hollow sphere with suitable holes for the nozzle and glow plug. The middle section, marked *2*, is a portion of a cylinder. The top section, marked *1*, is of spherical shape. It is important that these three parts be installed so as to permit entrance of the ends of the fuel nozzle. The top liner is held in position by means of a dowel pin.

Cylinder Head and Valves. The cylinder heads are not interchangeable, these being built in front and rear sections and marked to indicate the position for installation. The valves will be noted as of conventional design with the exception that the inlet is of unusually large size to insure a maximum amount of air reaching the cylinder on the inlet stroke. Specifications for setting the valves and in fact all other important specifications for maintenance of these engines, are given in the clearances tables.

Cylinder Block. The cylinder block is provided with removable sleeves. The water comes in contact with the outside surface of the sleeves or liners. Two rubber gaskets are used at the bottom of the cylinder block to seal the cooling water and keep it from reaching the crank case. Near the upper end of the sleeve, a copper ring gasket is placed between the counter bore of the cylinder block and the shoulder at the top of the liner or sleeve. This is located by means of a dowel pin.

Other features of engine construction are of considerable interest, as will be brought out in the discussion of the service of the engine. One of the chief points of difference between a gasoline engine and the Diesel type of engine is the method of fuel injection and the timing of the fuel injection, which amounts to the same thing as timing the ignition of the gasoline engine. Inasmuch as the understanding of the principles of the operation of the Diesel engine is dependent to such a large degree upon knowledge of the fuel injection, that feature of the engine design and operation is treated first. Later on is given a discussion, and the specific requirements of servicing the Diesel type engine are treated in detail.

HIGH-SPEED DIESEL ENGINES

PART I

FUEL-INJECTION SYSTEMS

Three features serve to distinguish the Diesel engine from the gasoline engine. First, the compression of the gasoline engine is low, ranging from 150 pounds per square inch downward to as low as 60 pounds, with 90 pounds the average for automotive engines; the Diesel employs a compression pressure of 400 pounds up to 550 pounds. Second, the gasoline engine draws into the cylinder during the suction stroke a mixture of air and gasoline vapor; the Diesel draws in a charge of air only, and the fuel is injected by some pump mechanism at the end of the compression stroke. Third, a spark ignites the air-fuel charge in a gasoline engine, while in the Diesel, compression to 450 pounds pressure raises the air temperature to 1000°F.; high enough to ignite the fuel when it is introduced.

Injection of the fuel at the end of the compression stroke is by no means advantageous *in itself;* in fact, if it were possible to do so, better combustion would result if fuel could be drawn in with the air charge during the suction stroke of the Diesel. The reason is that there is a greater time interval for complete mixing of fuel and oil during the flow through the intake manifold, suction stroke, and compression stroke, as compared to the limited time available when fuel is injected at the end of the compression stroke.

Injection of liquid fuel at the end of the compression stroke is imperative with the Diesel for the high compression raises the temperature of the air charge so high that if the fuel were in the cylinder during the suction stroke, spontaneous ignition would occur early in the compression stroke.

A high compression pressure is advantageous, for engine efficiency depends upon the compression pressure ratio as shown by the basic expression for all types of internal combustion engines, as given on the following page.

$$E = 1 - \left(\frac{1}{r}\right)^{Y-1}$$

where E = engine efficiency
r = compression ratio, or *maximum compression pressure*
suction pressure
Y = ratio of specific heats, or
1.408 for air

To obtain high efficiency, a high compression pressure is necessary which, to eliminate pre-ignition, requires fuel injection at the end of the compression stroke.

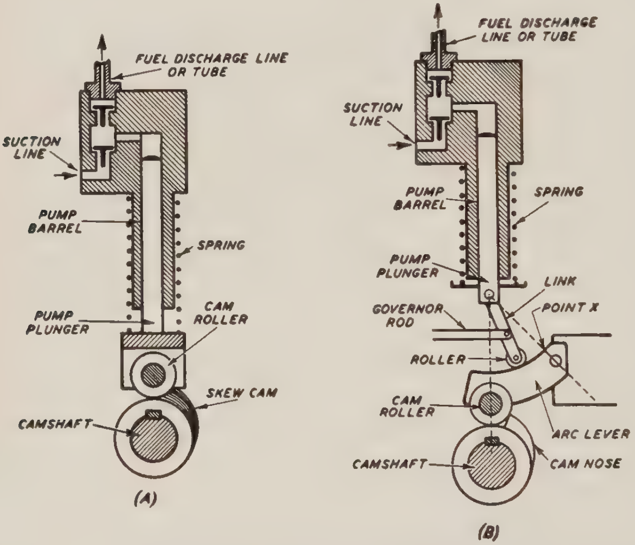


Fig. 22. (A) Showing an Impulse Pump with Variable Plunger Stroke (B) Showing Variable Plunger Stroke by Means of Arc Rocker Arm

Injection of liquid fuel is then a necessity and not an advantage save in an airplane engine where a carburetor works indifferently under supercharging conditions.

Two basic methods of fuel injection are found on high-speed Diesels. The most popular is *impulse injection,* or as it is commonly called, "jerk-pump" injection; the second is *hydraulic injection,* or "common-rail" injection. Both have their adherents, but it is generally accepted that "jerk-pump" injection is the simplest for high-speed engines.

Jerk-Pump Injection. In the "jerk-pump" system, shown at

(*A*), Fig. 22, a cam with a sharp nose rotates under the foot of the plunger working in the barrel filled with oil, and with a tube leading to the nozzle at the engine cylinder. The rotation of the camshaft at half engine speed brings the raised portion of the cam into contact with the pump plunger at a high velocity. The effect on the plunger is similar to the result if a lever was given a sharp jerk, consequently, the term "jerk-pump." The motion given to the pump plunger raises the oil pressure in the barrel and tube high enough to overcome spring pressure at the nozzle, and forces oil into the engine cylinder.

Fuel Control. The amount of oil injected into the cylinder is varied to meet the load conditions by anyone of several devices.

Fuel injection pumps are classified as (1) variable-stroke pumps, in which the length of stroke is mechanically varied to suit changes in the amount of oil required; (2) constant-stroke pumps, in which the plunger travel is of fixed length and variation in quantity is obtained by valve control.

Constant-stroke pumps, notwithstanding the somewhat complex valve control associated with them, have yielded successful fuel-injection systems.

Variable-Stroke Pumps. Variable-stroke pumps may be actuated either by constant-throw cams with variable-ratio linkage interposed between them and the plungers, as shown at (*B*) in Fig. 22, or by bevel-flank cams capable of giving a variable throw as the result of being shifted endwise as at (*A*) in Fig. 22. During the interval of injection the plungers are accelerated from zero speed up to their maximum, and then return quickly to rest under the influence of heavy springs.

In Fig. 22 at (*B*), the barrel and valves are identical with those at (*A*) in Fig. 22. The cam has a straight cam nose. This cam contacts with a roller of the arc lever which has an arc-shaped upper surface. Upon this upper surface rests another roller of the link which is pinned to the pump plunger. If the governor rod moves the link until its roller is exactly above the lower roller, then the pump plunger will have an upward travel equal to the lift of the cam nose. When the governor shifts the link until the upper roller is at point *X* on the arc lever, the plunger will receive no motion when the cam nose raises the lower roller and the left end of the lever.

Bevel-flank cams for multi-cylinder engines are generally milled on a solid sleeve which is splined to the camshaft and arranged to be moved sidewise along the camshaft by the governor or other regulating mechanism. The cam rollers, shown in Fig. 22 at (*A*), for driving the plungers are either ground to a bevel corresponding to that of the cam, or they may have semi-circular faces adapted to make them move readily on the sloping contours of the cam surface. The force necessary to make the plunger move against the spring force and fuel pressure acts on the sloping cam in such a way as to urge it sidewise, so that considerable force must be exerted in positioning the latter for purposes of load control. In truck and tractor engines, the force necessary for moving the cams can be supplied readily by the foot pedal, but if the engine is governor controlled, the governor must be of adequate power for the service. In view of the limited area of contact between the cam and roller faces, it is essential that the latter be made of the highest-grade materials. Good continuous lubrication must be provided and dilution of the oil, with fuel dripping from the pump, must be effectively guarded against by means of positive deflectors.

Constant-throw cams of the normal type can be made to impart variable motion to a pump plunger by means of a wedge, as in Fig. 23. The position of the wedge may be controlled by a link connected either to a governor or a short crank on the control shaft. If the wedge is moved to the right, Fig. 23, the length of travel which it imparts to the pump plunger is increased.

Constant-Stroke Pumps. Constant-stroke pumps are valve-controlled by five general methods: (1) throttling the suction inlet; (2) bleeding the pump chamber with a needle throttling valve, as in Fig. 24 (almost the same as 1); (3) controlling the time of seating of the suction valve, Fig. 25. Here the lever fits in a slot in the plunger and its outer end contacts with the stem of the valve. The eccentric is shifted by the governor to cause the rocker to leave the valve stem earlier or later; (4) by-passing from the pump chamber by opening a special spill valve at various percentages in the discharge stroke, Fig. 26; (5) relieving the pump by the piston uncovering a by-pass or suction port during the discharge stroke, as in Fig. 27.

Suction Throttling. Suction throttling regulation has the advantage of extreme simplicity and is adaptable mainly to small pre-combustion chamber engines requiring low injection pressures. As the suction movement prevents the pump from drawing in a full oil charge, a certain amount of vacuum is created and the pump chamber becomes partially filled with fuel vapor and sometimes air if there is leakage. During the return stroke, delivery does not start until the gaseous elements in the pump chamber have been compressed and accuracy, at the beginning of injection, is to some extent sacrificed.

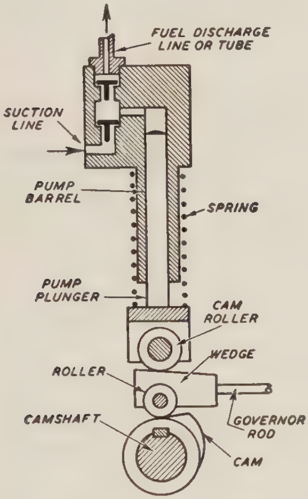


Fig. 23. Variable Plunger Stroke by Means of a Wedge

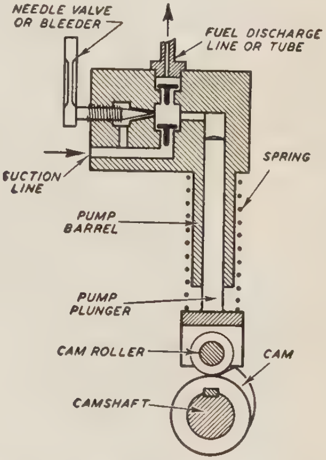


Fig. 24. Fuel Charge Delivered by Pump Is Controlled by a Bleeder Valve

Suction Valve Control. Suction valve control, Fig. 25, is generally carried out by some reciprocating mechanism which moves in rhythm with the pump plunger and momentarily interferes with the seating of the valve. As the plunger begins its discharge movement, the suction valve moves toward its seat, for its spring causes it to follow the motion of the rocker. Actual delivery begins at the moment when the suction valve touches its seat and the rocker breaks contact with the end of its stem. From that point on, until the plunger ends its stroke, oil is discharged.

The suction valve mechanism may derive its motion either from the plunger crosshead, as in Fig. 25, or from a cam or an eccentric mounted on the shaft which drives the plunger. In nearly all cases, the essential part of such a regulating valve is a rocker arm pivoted on the eccentric. The latter is placed in various positions, by hand or governor control, and changes the point of time at which the suction valve is allowed to touch its seat. The earlier this occurs, the more oil is delivered, and the greater is the angle of advance of injection. Although this change in timing would be impracticable with most forms of open combustion-chamber airless-injection engines, it apparently makes no difference with single-orifice pre-combustion chamber machines of low rating. A pronounced advantage of the suction-valve method of regulation is that the control mechanism, governor, etc., are not influenced by the injection pressure, which begins to build up only after the suction valve has seated and has lost contact with the control device.

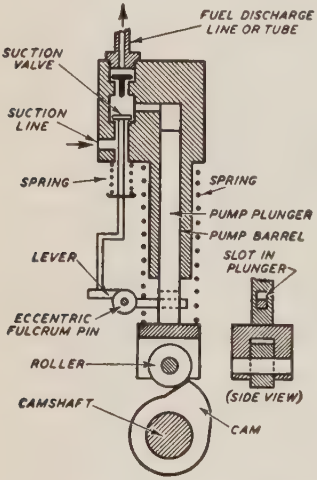


Fig. 25. Pump with Controlled Suction Valve

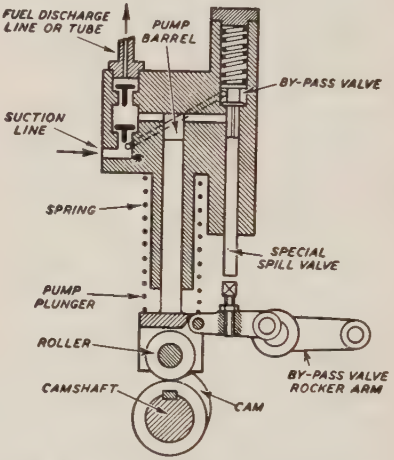


Fig. 26. Fuel Controlled by Opening the By-Pass Valve

Spill-Valve Control. Spill-valve control, Fig. 26, is effected in the majority of designs by a special spill valve, distinct both from the suction and discharge valves, and which is thrust open by the same kind of mechanism (rocker arm) as that generally used for suction valve regulation. The suction valve itself is not generally used for this purpose because its comparatively large area is subject to the full injection pressure and would, therefore, require a disproportionately large force to open it, imposing severe mechanical reactions on the regulating and governor mechanism. Hence, the mechanically-actuated spill valve is generally made of the smallest possible area. A compromise must be effected, however, because if the spill valve is too small, it will cause the fuel injection pressure to fall too slowly, and the fuel line between the pump and the spray valve will not relieve itself promptly and will encourage "after-dripping" at the spray nozzle. With these arrangements, the regulating tappet moves toward the stem and tappet of the spill valve, making contact with it at the moment when injection is to be terminated. The timing of the beginning of injection is therefore constant, whereas its end is a variable depending on the amount of fuel injected.

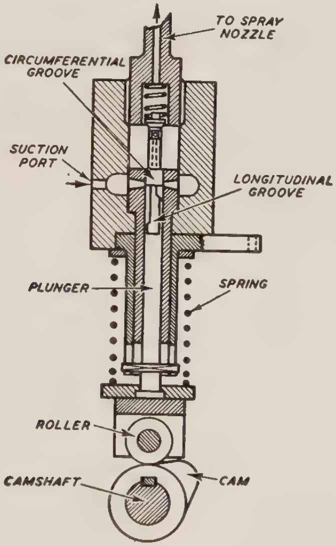


Fig. 27. Fuel Controlled by Location of Pump Plunger

Port-Controlled Fuel Pumps. Port-controlled fuel pumps, Fig. 27, generally operate with plungers having grooves of suitable contours cooperating with openings in the side of the pump barrel. In the lowermost position of rest, the plunger's upper edge stands below the suction port, and oil is thrust back into the suction chamber during that portion of the upward stroke which is necessary to traverse the width of the port and close it. Delivery then begins.

A longitudinal groove leading to the upper end of the plunger connects the pump chamber with an annular space around the plunger formed by milling a circumferential groove or neck in it, and delivery continues up to the point where this neck again uncovers the suction opening. This is the most popular design and is employed on 90 per cent of high-speed Diesels.

Distributor System. A development of the "jerk-pump" system is the "distributor" system. Here a single pump delivers a charge of fuel to a disk which rotates and consecutively brings the pump into communication with each fuel line leading to the nozzle in the several cylinder heads. This is shown schematically in Fig. 28.

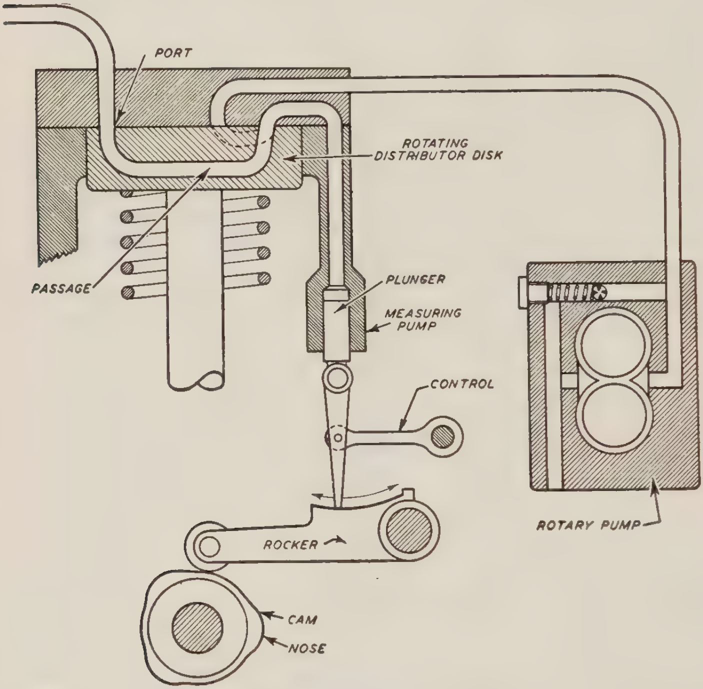


Fig. 28. Fuel Pump Delivered through a Distributor to the Several Engine Cylinders

The rotary pump is driven from the engine camshaft. Oil is delivered to the measuring pump. This is driven by the cam through the rocker. The cam has three noses on a six-cylinder engine. The camshaft runs at engine speed and as a nose comes under the roller of the rocker, the plunger moves upward, to deliver a charge of oil to the distributor. This distributor contains as many ports in its cap as there are engine cylinders. Each port leads to an engine cylinder.

The distributor is driven at engine speed and consecutively brings the port for each cylinder into communication with the pump through the passage in the disk. In this way, one pump serves all the engine cylinders. The advantage is that each cylinder receives the same amount of fuel. The quantity is varied by the control which shifts the pump plunger rod along the arc of the rocker. This is the principle of the Cummins Diesel system.

"Common-Rail" Systems. Basically, the "common-rail" fuel-injection system is made up of a pump which is constantly delivering a supply of oil to a header, or "common-rail" with laterals from this header to the fuel spray valves at each cylinder head. These needle type spray valves are held to their seats by springs and are lifted by a rocker and cam, whereupon oil in the header sprays into the cylinder as long as the cam holds the needle in the open position.

When the cam permits the needle to seat, the oil flow into the cylinder ceases. The header must be large enough that the oil flow through a spray valve will not affect the pressure in the header. The fuel pump must supply an excess of oil above the amount entering a cylinder, and to prevent excessive pressure by reason of the oversupply, the header has a spring-loaded by-pass valve which by-passes enough of the oil pumped to maintain a constant header pressure. Only one American high-speed Diesel employs a "common-rail" system; this is the Atlas-Imperial high-speed Diesel.

Fuel Spray Valves. With the exception of the common-rail engine just mentioned, all high-speed Diesels in this country employ differential-needle spray valves of the general type shown in Fig. 29. Oil is delivered by the fuel pump to the fuel line. This oil flows down the passage to the chamber *A* at the bottom of the spray valve casing. The continued movement of the oil displaced by the pump raises the pressure in this chamber until the total pressure acting on the differential area created by the two diameters of the needle valve, overcomes the force of the spring. The needle valve lifts and the lower tip leaves its seat, so that oil flows through the orifice into the engine cylinder. As soon as the tip leaves its seat, the total area upon which the oil pressure acts, to hold the needle away from the seat, is increased by the cross-sectional area of the tip itself. Consequently, once the needle opens, this excess pressure lifts the needle still higher. As soon as the pump slows down its delivery of oil, the pressure in the oil chamber falls, but the needle will not drop down onto its seat until the pressure drops below the pressure which caused the needle to lift. Consequently, if this closing pressure is too low, the oil spray through the orifice will be coarse and the oil may even dribble in drops, resulting in poor combustion.

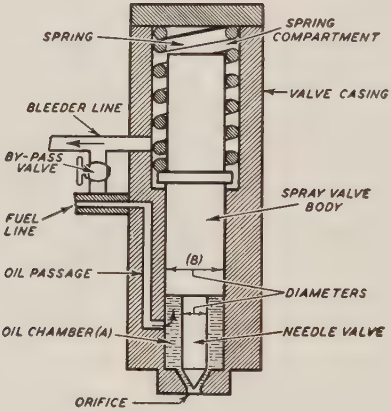


Fig. 29. Differential-Needle Spray Valve

The oil pressure at which the needle lifts depends upon the strength of the spring. After the needle opens, the oil pressure depends upon the area of the orifice in relation to the pump plunger displacement. Too large an orifice will cause the oil pressure to drop, which may then be less than the spring pressure, whereupon the needle will be forced to its seat. Since no oil now flows through the orifice, the pressure on the differential area will rise. In turn, the increased oil pressure will overcome the spring force, to lift the needle. Flow through the orifice will be resumed, and the oil pressure will again drop, closing the needle valve. This continued action is termed "chattering" and results in poor combustion.

To correct the difficulty, the orifice diameter should be reduced, by replacing the tip.

When "chattering" occurs with the correct orifice diameter, the spring pressure may be too strong. The pump then must raise the oil pressure unusually high, to lift the needle, and rate of flow of oil through the orifice is increased by reason of the high oil pressure. This rate may be so high that the pump does not maintain the pressure; consequently, the spring forces the needle to its seat.

Orifice Diameter. The diameter of the spray orifice will vary from 0.01 to 0.02 inch diameter. The minimum diameter depends upon mechanical limitations, for it is difficult to drill a satisfactory hole below 0.01 inch. Furthermore, an orifice of less than 0.01 inch almost becomes a filter and is liable to become clogged with minute dirt particles.

Obviously, the smaller the orifice the finer will be the atomization. When the quantity of oil handled is above the capacity of one small orifice, the designer adds more orifices, so that in the larger engines as many as 10 orifices of 0.02 inch diameter are used in one spray valve.

Spray Pressure. The pressure under which the oil is placed to lift the needle valve, varies according to the engine design, ranging from 10,000 pounds per square inch down to 2000 pounds. An average value of high-speed Diesels of 3¾-inch to 6-inch cylinder bores is 5000 pounds.

Bleed-Off Line. There must be some clearance between the enlarged diameter *B,* Fig. 29, of the needle and the valve casing. Oil will creep up along this clearance and finally build up an oil pressure in the spring compartment, which acting upon the upper end of the needle, will prevent the oil pressure acting below the enlarged diameter *B,* from lifting the needle. To eliminate this, the "bleeder" line permits the seepage oil to escape.

In order to prevent oil from entering the engine cylinder in case of trouble, the by-pass valve can be opened. This allows the oil flowing to the by-pass valve through the fuel line to pass directly through the valve by-pass to the bleeder line.

Carbonized Orifices. If an engine operates at heavy load and the cooling of the spray valve is inferior, carbon will build up on the end of the nozzle tip within the cylinder. This carbon will be in the form of a hollow cone, and more and more carbon accumulates until the nozzle becomes clogged. To correct this, some nozzles are provided with a cooling water passage, to keep the tip cool and carbon free.

Scored Needles. Dirt may settle on the valve seat and damage the seat and needle tip when the spring pressure snaps the needle to its seat. While an experienced mechanic is able to regrind the parts, the better method is to replace the defective parts with new ones.

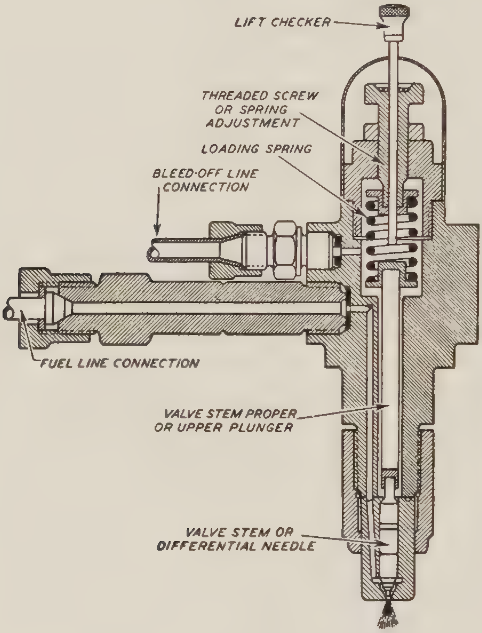

LIFT CHECKER
THREADED SCREW OR SPRING ADJUSTMENT
LOADING SPRING
BLEED-OFF LINE CONNECTION
FUEL LINE CONNECTION
VALVE STEM PROPER OR UPPER PLUNGER
VALVE STEM OR DIFFERENTIAL NEEDLE

Fig. 30. Bosch Spray Valve

Typical Spray Valve. Many Diesel builders use the Bosch spray valve, Fig. 30. The valve-stem is lapped (fitted accurately) in the guide bushing to a fit which makes any form of packing unnecessary; as a matter of fact, packing cannot be used without danger of the stem becoming too tight when the packing is compressed. An air vent should be provided at the uppermost part of the nozzle, to dispose of any air which may accumulate in the fuel line or in the nozzle, thereby avoiding "air binding."

In the Bosch design, the nozzle and guide bushing are integral. The nozzle holder is secured to the cylinder head by the usual yoke and studs. It contains the loading spring and the threaded screw for adjusting the spring pressure, and is threaded at its lower end for the holding nut that secures the nozzle proper. The faces of the nozzle and its holder are ground and lapped to assure a good fit and freedom from leakage at any pressure. At the side of the holder are two connections, one for the fuel line and the other a bleed-off line to carry off, usually to the service tank, any fuel that may leak past the valve-stem. The loading spring is housed at the upper end of the nozzle holder, which is naturally the coolest portion. The lower end of the spring rests on a cap which in turn rests on the valve-stem proper, and the upper end abuts on the adjusting screw. A protecting cap covers the adjusting device. The holder is also equipped with a feeler pin which passes through a central hole in the adjusting screw. If this pin is depressed by the finger, the motion of the nozzle stem can be felt. This provides a convenient way to determine whether the nozzle is functioning.

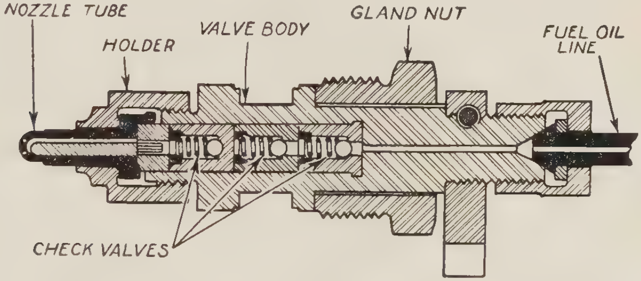


Fig. 31. Ball Check Section of Hesselman Spray Valve

Hesselman Nozzle. In Fig. 31, is shown the spray valve used on the Waukesha-Hesselman oil engine. This is essentially a valve body in which are placed three ball check valves and to the end of which is screwed the holder clamping the nozzle-tip tube to the valve body. Oil enters the fuel oil line. The gland nut screws into an opening in the cylinder head and locks the spray nozzle in place.

It will be noticed that the ball valves permit the flow of oil without overcoming any great spring pressure. The balls are solely for the purpose of preventing cylinder gases back flowing into the fuel oil line.

The spray valve is used with a low oil pressure and a low cylinder compression pressure. It is an "open," that is, low-pressure, nozzle.

Westinghouse Spray Valve. A second differential-needle spray valve is employed on the Westinghouse high-speed locomotive Diesel. As will be seen from Fig. 32, oil enters at the fuel intake and exerts pressure on the lower area of the enlarged section of the needle. The orifice carries five holes and the entire tip is replaceable. The lifting pressure depends upon the spring whose compression is alterable by turning the adjusting nut. The pipe line is the "bleed" off line.

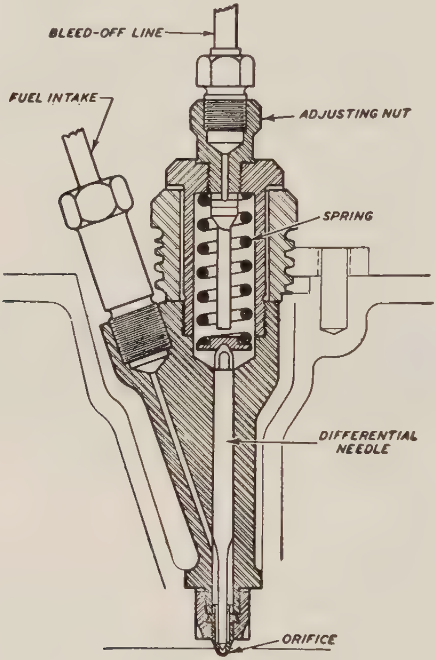


Fig. 32. Spray Valve of Westinghouse Diesel

Bosch Injection Pumps. The Bosch injection pump is employed by over 75 per cent of Diesel builders and the general design is found in 90 per cent of all American high-speed Diesels.

The Bosch pump, Figs. 33 and 34, may embrace all the pump plungers for the several engine cylinders in a single casing, or a separate casing may be employed for each pump plunger. The control of fuel delivered to spray nozzle is by pump-plunger by-pass.

As shown in Fig. 33, each pump element consists of a cylinder and a piston or plunger. The cylinder is closed at its upper end by a spring-loaded pressure valve, from which the fuel line leads to the injection valve.

In the upper part of the housing is a suction space which is connected with the fuel tank by means of the suction pipe. Two small holes connect the suction space with the pressure space in the pump cylinder. The stroke of the plunger is constant. The upper edge of the plunger controls the beginning and the slanted groove controls the end of the fuel delivery. The end of the delivery is reached sooner for a small quantity of fuel than for a large quantity, brought about by turning the pump plunger into various positions.

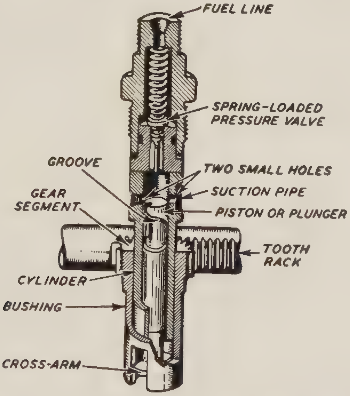


Fig. 33. Diagram of Bosch Fuel Pump

The pump cylinder is enclosed by a bushing to the upper end of which a gear segment is fastened. This segment, in turn, engages with a toothed rack which is actuated manually or by a governor. The lower end of the bushing has two opposite slots in which a cross-arm of the piston is guided; the angular motion of the bushing, caused by sliding the control rod, being thereby transmitted to the plunger. No fuel is delivered by the pump when the control rod is at one extreme position; in the opposite position, the maximum quantity of fuel is delivered.

The operation of the pump is shown in detail in Fig. 35. In the lowest position of the piston, the two opposite ports are opened and the cylinder which is above the piston is then filled with fuel.

During the first part of the pressure stroke of the piston, a small quantity of fuel is forced back into the suction space, until the plunger closes both port holes. From then on, the fuel is put under pressure and the pump begins to force it through the check valve and the fuel line into the injection valve.

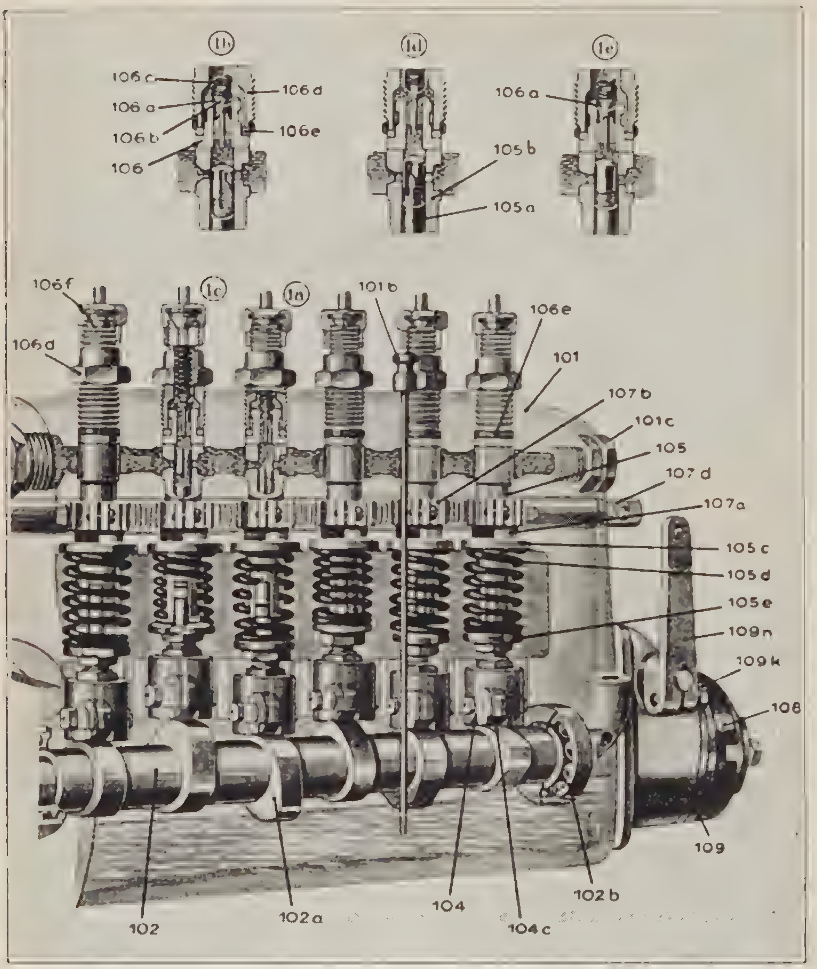


Fig. 34. Bosch Fuel-Injection Pump

101b—Gauge Rod
102 —Cam Shaft
104 —Tappets
104c—Cam Roller

105d—Springs
106 —Seat
106b—Delivery Valve
106c—Spring

106d—Pump Delivery Valve Holder
107b—Toothed Segments
107d—Control Rod

Delivery begins as soon as the plunger has covered the ports on the way up, and ends as soon as the sloping edge, indicated by the arrow, opens the port hole on the right-hand side and permits the fuel to escape from the pressure space above the plunger, through the groove in the plunger and the port, to the suction space.

In the two views at the left, the plunger is shown in the position for maximum delivery, in which the edge of the helical groove does not open the port hole at all. The next two views 3 and 4, show the position of the plunger for medium delivery of fuel, and the one at the right shows the position when no fuel is being delivered.

The discharge valve has another important task to perform. It is highly desirable to relieve the pressure in the fuel line in order to obtain a rapid closing of the injection valve, as otherwise dripping of fuel from the nozzle into the combustion-chamber may occur. A special construction of the valve provides this pressure relief in an effective and reliable way, as follows:

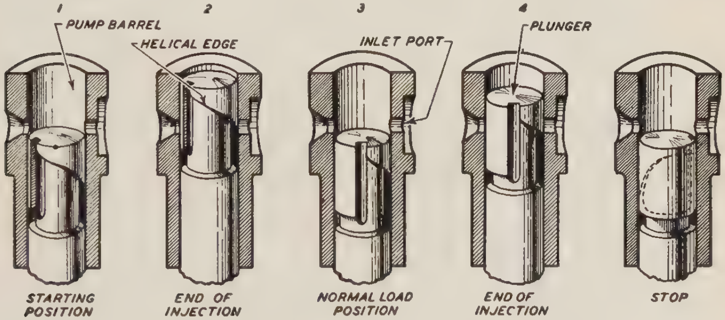


Fig. 35. Action of Bosch Plunger

During the working stroke of the pump, the valve is raised from its seat and the fuel flows through the hollow stem and two connecting holes into a ring groove, and from there to the fuel line. Adjoining the ring groove is a short cylindrical surface forming a shroud, and above this is the valve head. When the by-pass opens, the valve closes. In doing so, the receding valve stem causes an increase in the volume of the fuel line by an amount equal to the volume of the shrouded part of this valve stem. The fuel in the line is in this way suddenly relieved of its pressure, and rapid closing of the injection valve is effected.

A pump, such as that shown in Fig. 33, is operated by reciprocating motion provided for in the design of the engine, from the camshaft or in some other suitable way. Pumps of this sort are made in various sizes, the largest delivering 5400 cu. mm. (3.295 cu. in.) of fuel for each working stroke. The self-contained type, Fig. 35, has a camshaft, individual cams and rollers for each pump element. Such pumps are available in sizes up to that required for a four-cycle engine having 280 cu. in. displacement per cylinder and requiring approximately 260 cu. mm. (0.159 cu. in.) of fuel for each working stroke.

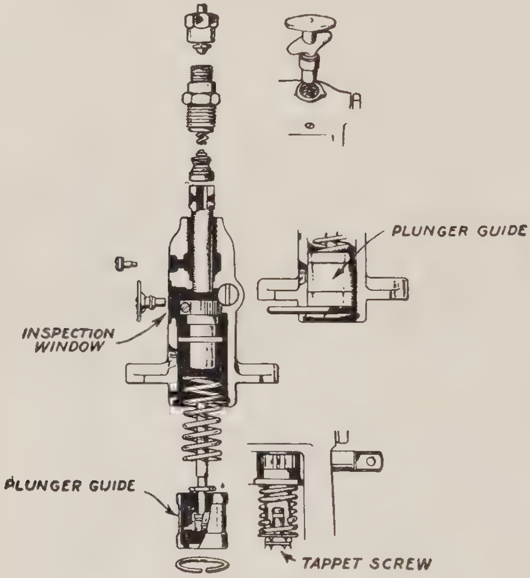


Fig. 36. Parts of the Bosch Pump Showing Timing Marks

Adjusting Bosch Pump Timing. To facilitate the adjustment of the fuel-injection pump and the timing of the fuel injection, an inspection window, Fig. 36, is provided in the pump casting, through which the mark on the plunger guide should always be visible when the pump plunger is at top dead center of its stroke. The beginning of the injection is indicated when the mark on the plunger guide coincides with the mark on the side of the window. This adjustment is, however, only correct for a certain opening pressure of the nozzle and for a certain speed of the pump. The mark on the plunger guide should coincide with the mark on the side of the window when the engine crankshaft stands at the number of degrees ahead of top dead center as called for by the engine builder's timing data. Top dead center for the engine crankshaft is indicated when a line that is marked on the flywheel comes even with a line that is marked on the end plate. A tappet screw is provided directly under the fuel-injection pump. This screw is held with a locknut. By loosening the locknut, the tappet screw can be adjusted to either raise or lower the line on the fuel-pump plunger guide at the will of the operator. Great care should be exercised when moving this screw to see that the mark on the plunger guide is still visible in the inspection window at both the top and bottom of the pump plunger travel. Serious injury to the pump may result if the pump plunger is raised or lowered too far by the tappet adjusting screw.

Dismantling Pump. In overhauling a Bosch pump, the pump plunger or its barrel should never at any time be touched with a file or other hard tools. Should these parts be damaged, the pump should be sent to the nearest Bosch Branch for attention.

The delivery valve and its seating should also be kept together as a pair always and should never be ground in with grinding powder of any kind, as this will ruin them entirely. If, when they are cleaned and rubbed together, trouble is still experienced, the pair should be replaced from spares.

If, in multi-cylinder block pumps, it is considered necessary to dismantle the pump-element control sleeves and control rod, these parts must be readjusted together after reassembling with great accuracy to ensure that all pump elements will deliver identical quantities of fuel to all engine cylinders. The procedure of dismantling is shown in Fig. 36, and is as follows:

(1) Push the plunger guide up until a service pin can be inserted into the dowel hole provided in the spigot of the pump flange, when it will be an easy matter to remove the spring ring. On removing the service pin, the plunger guide, the lower spring, the plunger spring and the plunger can now be easily withdrawn.

(2) Unscrew the delivery-valve holder, withdraw spring and

delivery valve. The valve seating and its joint can now be removed by means of a special lifting tool which can be obtained from any Bosch Branch.

(3) To remove the pump barrel, unscrew the locking pin and push the barrel from below by means of a fiber or soft-brass rod.

In reassembling the pumps, great care should be taken that all joints and other parts are entirely clean. These should be (1) rinsed in clean kerosene, (2) allowed to drip, (3) smeared with a little lubricating oil and finally brought together entirely without the use of cotton waste or rags.

In the following notes, the work "pump" should be read to mean each pump element in a multi-cylinder block pump:

(1) Refit the barrel carefully, taking care that the slot in it is opposite the hole for the locking pin. Tighten down the locking pin after making sure that its joint is in place.

(2) Refit valve seating and place it cleanly and securely in position. Place delivery valve and its spring in position. Fit delivery-valve holder with its joint in place and screw down tight.

(3) Insert control rod in mid-position (which is marked with two center punch points). Insert plunger fitted with lower spring plate and spring into pump barrel, taking care that the lug on the lower end of the plunger is fitted into the slot in the control sleeve for which it is marked.

(4) Insert plunger guide and push up until a pin may be fitted through the hole provided in the flange spigot so that the spring ring may be fitted into its groove.

Ex=Cell=O Fuel Pump. As shown in Figs. 37 and 38, the Ex-Cell-O pump employes a "wobble"-plate which is rotated by the shaft which, in turn, is driven by gears from the engine crankshaft. The rotation of the wobble-plate also causes the shoe to move parallel to the shaft axis, that is, moves to the left and down. The motion is transmitted to the rod whose end contacts with the end of the pump plunger. The plunger, when it moves to the right, draws in a charge of oil and on the return, or left, stroke, discharges the oil through the connection to the cylinder spray valve. There is a plunger, rod, and shoe for each engine cylinder.

Oil reaches the plunger barrel through a port in the rotating suction valve shaft, which is driven through a spline by the shaft.

The amount of oil reaching the pump barrel depends upon the position of the port when it rotates past the fuel passage. A governor, acting through the lever, shown in the upper drawing, moves the suction valve shaft to the left or right, as the case may be, and so presents more or less of the port opening to the fuel passage. This pump has, then, a "throttling-suction" type of control.

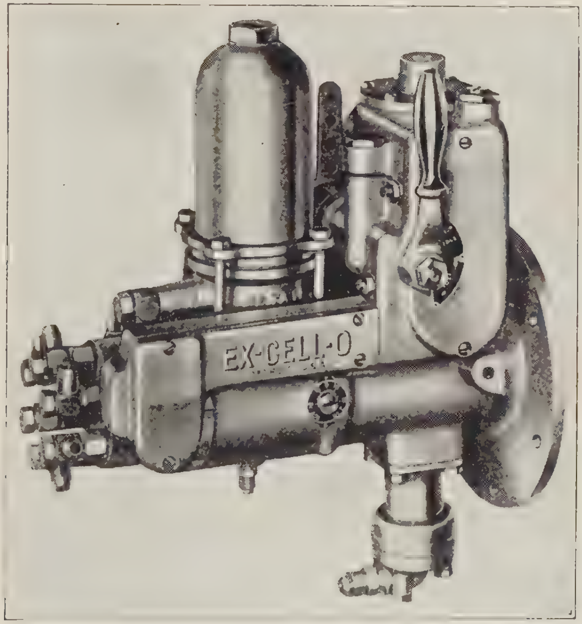


Fig. 37. Showing Ex-Cell-O Fuel Pump Assembled
Courtesy of Ex-Cell-O Aircraft & Tool Corporation

All plungers, six in case of a six-cylinder engine, are lapped in the barrels which are bored in a single-cylindrical block of steel.

Since a single valve controls all pump cylinders, there should be identical amounts of oil delivered to each engine cylinder.

Timing of Ex-Cell-O Pump. Timing of the Ex-Cell-O pump is accomplished by shifting the gears connecting it to the engine crankshaft. A cross-sectional view of the pump is shown in Fig. 38.

Cummins Fuel System. The fuel-injection system of the Cummins Diesel is radically different from that of any other Diesel.

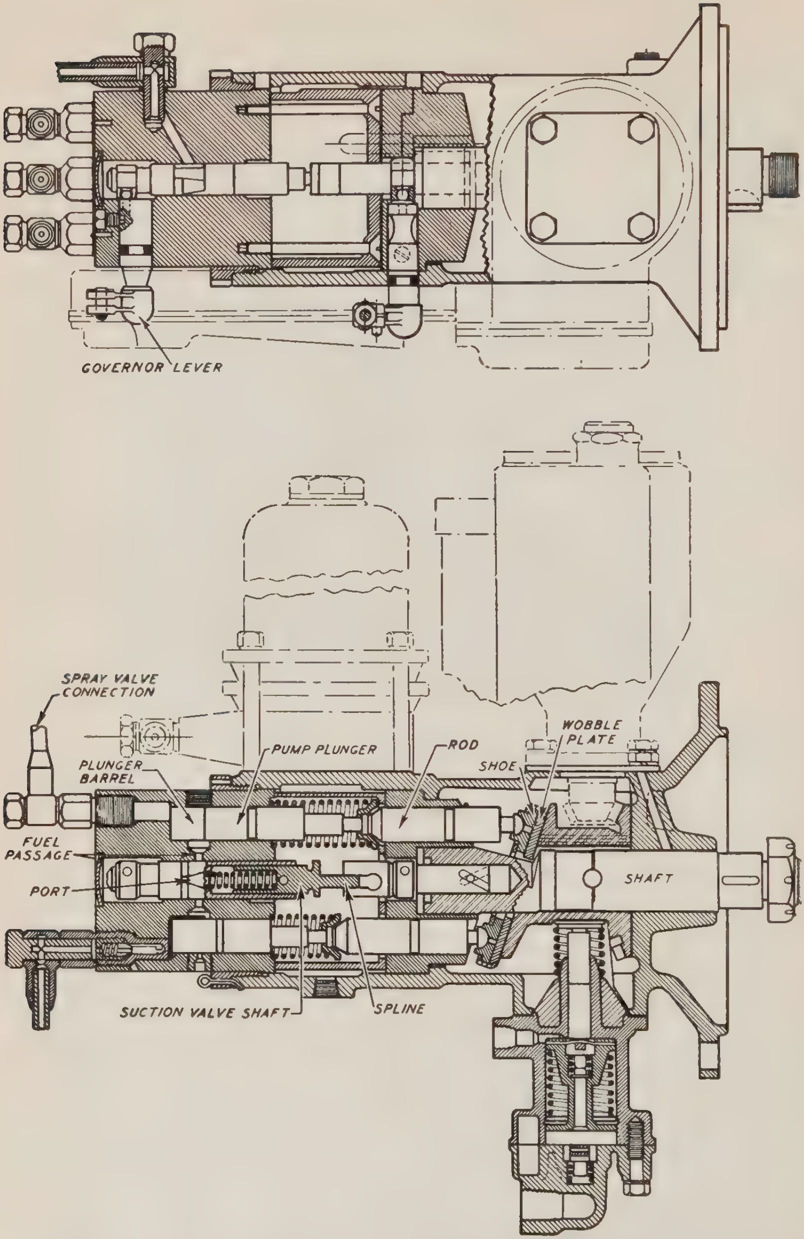


Fig. 38. Showing the Cross-Sectional View of the Ex-Cell-O Fuel Pump.

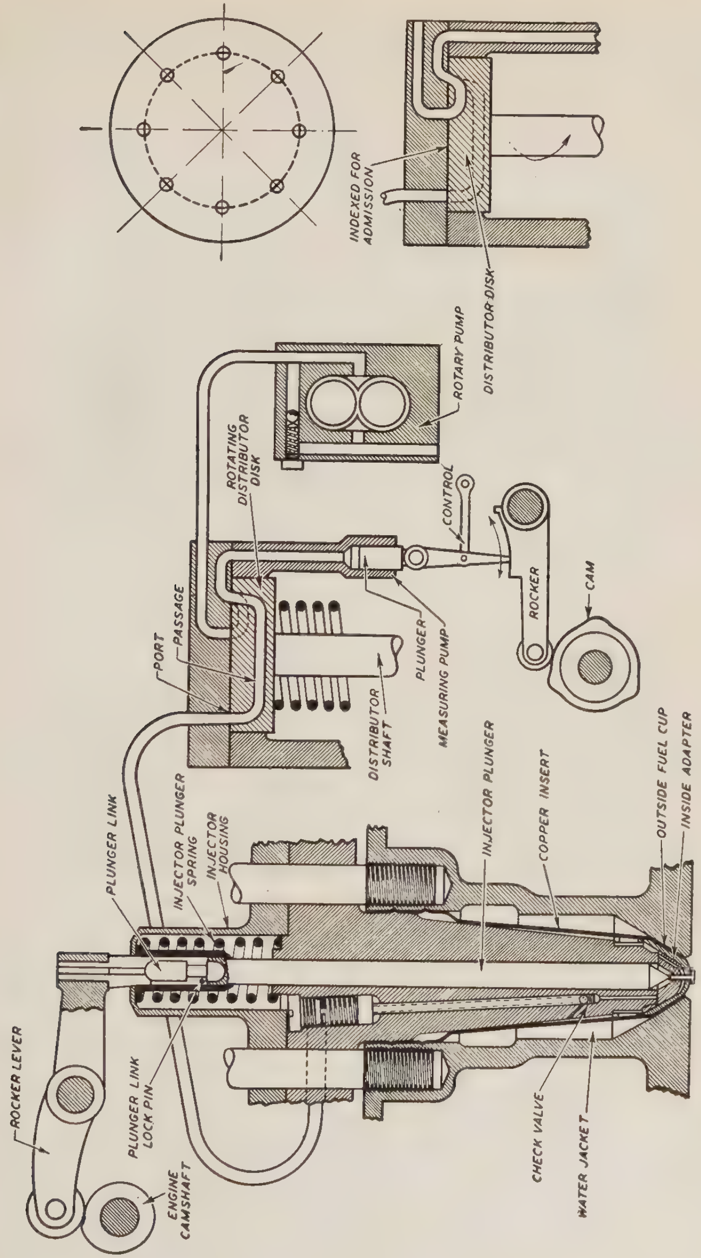
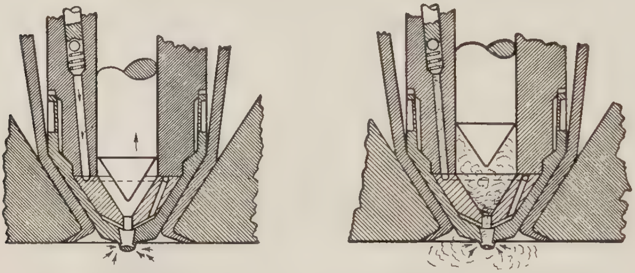


Fig. 39. Cummins Fuel System

While the fuel pump and the distributor were shown in Fig. 28, a diagram of the entire fuel handling system is shown in Fig. 39, and the pump parts are the same as those which are shown in Fig. 28.

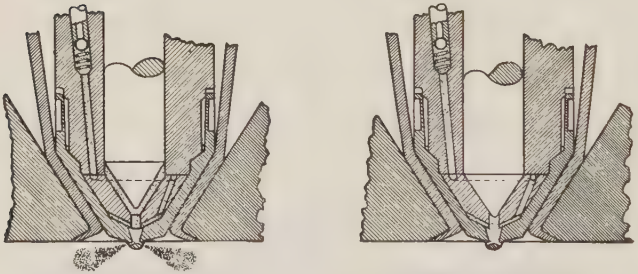
The spray valve, or as the Cummins device is called, the vaporizer is of interest.

The injector is mechanically operated and very simple in design.



A-FUEL CHECK VALVE OPEN; PLUNGER MOVING UP AND FUEL ENTERING CHAMBER

B-PLUNGER AT TOP POSITION; HOT AIR FROM COMPRESSION BEING FORCED THROUGH FUEL CHARGE



C-PLUNGER MOVING DOWN DRIVING GASIFIED FUEL CHARGE INTO COMBUSTION CHAMBER

D-PLUNGER SEATED AND INJECTION FINISHED

Fig. 40. Action of Cummins Fuel Injector

It consists of a special casting with a properly fitted plunger. Mounted on the end of the interior body is a screw cup containing a small cone-shaped adapter which seats on the end of the injector body. Between the screw cup at the lower end and the cone adapter is a small annular space. A connecting hole to the annular space leads up through the injector body to the fuel line from the pump distributor. This forms a passage from the fuel pump to the annular space in the cup. A series of small holes leads from the annular space to the inner cone and permits the fuel to pass into the injector-plunger chamber. On the intake stroke of the engine, the fuel-metering pump forces a charge of fuel of the right amount, for the load and speed, to the engine into the annular space between the cup and cone adapter.

The fuel lies in this inner chamber during the compression stroke of the engine, and the heated compressed air is forced through the small spray holes in the screw cup. The oil, being exposed to the heat and blasting of the compressed air, is broken up or gasified. A few degrees before top center, the mechanically operated plunger starts down, and the gasified fuel charge is driven out into the combustion chamber where it burns, clean and completely. A small check valve is located in the lower end of the fuel passage in the injector body. This prevents the compression from blowing the fuel back and filling the lines with air. The action is shown in Fig. 40, where the diagrams outline for phases of fuel injection.

Atlas-Imperial System. On its high-speed Diesels, Atlas-Imperial employs its "Atimco" system, Fig. 41.

All the desirable characteristics of the common-rail system have been retained in the "Atimco" system, but all delicate adjustments are eliminated. Instead of mechanically operated valves for each cylinder, this unit is operated with a distributor and fuel metering valves, which are supplied with fuel by a constant-pressure accumulator.

The injection unit consists briefly of two control valves and one distributor valve. One valve determines the beginning of the injection, and the top of it is also acting as the plunger for the high-pressure fuel pump. This unit as a whole will be referred to as the "pump unit." The other valve which is in the "governor non-control unit," determines the end of the injection, and also takes care of relieving the injection lines after the injection process is completed, thus preventing any after-drip. Finally, the distributor valve in the "distributor unit" determines to which cylinder the measured charge of fuel is delivered.

Referring to Fig. 41, the injection unit has two shafts, the drive shaft and the eccentric shaft. The eccentric shaft drives both the pump and governor-control units, but in order to explain their functions they have been shown side by side.

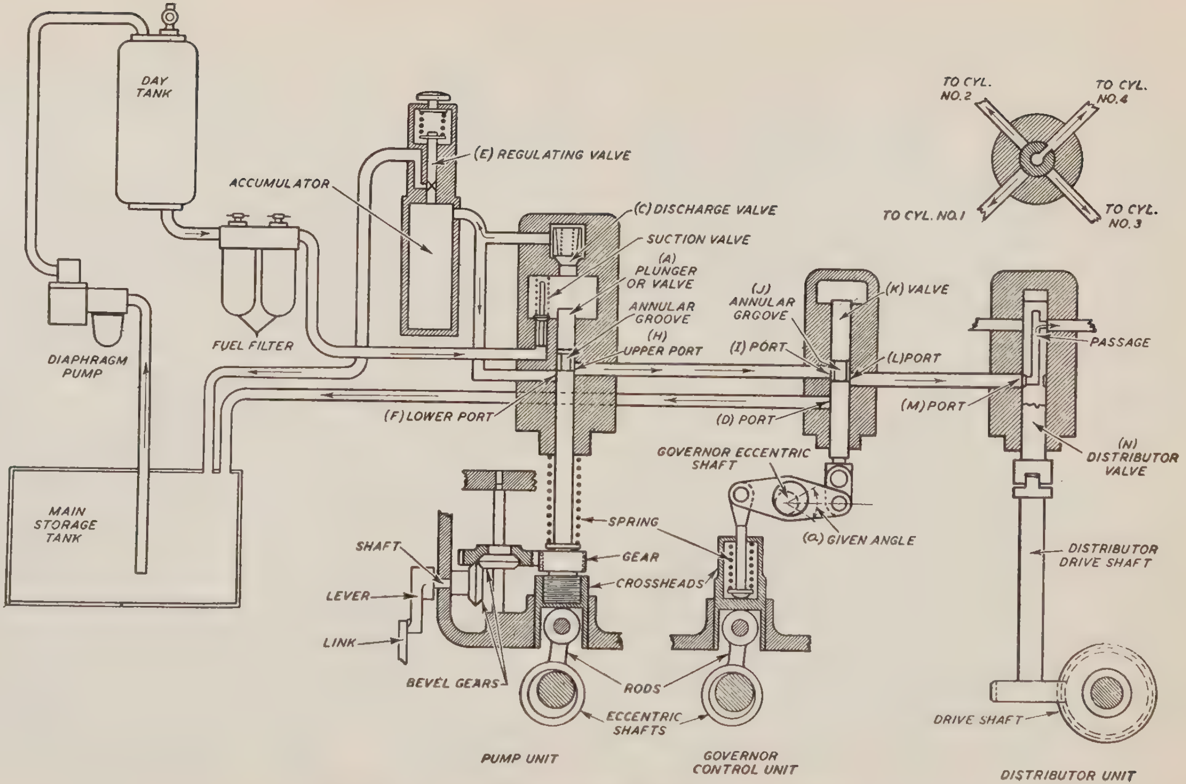


Fig. 41. Atlas-Imperial Atimco Fuel-Injection System

The drive shaft is driven through the timing gear train at engine speed, and is connected to the eccentric shaft by gears with 2 to 1 ratio, so that the eccentric shaft runs at twice engine speed on a four-cylinder engine. The drive shaft also drives the distributor valve *N* through the distributor drive shaft and helical gearing at one-half engine speed.

The plunger or valve *A* in pump unit is driven by the crosshead which in turn is actuated by the eccentric shaft by means of a rod. A gear is screwed into the crosshead and a spring holds the lower end of the plunger against the gear so that it will always follow the motion of the crosshead. Valve *K* in the governor-control unit is also made to follow the motion of the crosshead by means of the spring, push rod, and rocker on the governor eccentric shaft. During the downstroke of the plunger, fuel under slight pressure from the diaphragm pump flows through the day tank and fuel filters into the pump chamber above the plunger through suction valves (only one valve shown). During the upstroke of the plunger or valve *A*, this fuel is forced out of the pump chamber through the discharge valve *C* into the accumulator, where it is maintained under approximately constant pressure by regulating valve *E*. Any excess fuel over what is required to maintain the constant pressure in the accumulator is by-passed by the regulating valve back to the main tank or the day tank. The accumulator is also connected to the port *F* in the pump-unit body, so that at port *F* there is always full-fuel pressure irrespective of the position of plunger or valve *A*.

In Fig. 41, the positions of all valves are shown when injection is about to begin. The plunger or valve *A* is on its downward stroke, and when the lower edge of the annular groove in the plunger registers with the upper edge of port *F*, the fuel under high pressure can flow through this annular groove into port *H*. From port *H* it flows through a short connecting tube to port *I* in the governor-control unit. At this time, valve *K* is also traveling in a downward direction, and as the annular groove *J* is uncovering ports *I* and *L*, the fuel can flow through the governor-control unit into the distributor-unit port *M* by means of a short tube. From port *M*, the fuel can enter the passage in distributor valve *N* irrespective of its position. At this time, the other end of the passage registers with one of the ports communicating with the spray valves in the cylinder heads. Consequently, the fuel stored under high pressure in the accumulator is free to flow to the injectors in the cylinder heads and the injection process begins.

As the shafts in the pump and distributor unit continue to turn, the valve *K* moves in a downward direction. After a certain period of time, depending on the position of the governor eccentric shaft, the upper edge of the annular groove *J* in valve *K* closes port *I*, thus terminating the injection. In Fig. 41, the eccentric shaft is shown in the position for maximum fuel charge. The eccentric shaft has two centers, one around which the shaft rotates and the other around which the rocker oscillates. When the governor is holding the shaft in the position for full-fuel charge, the rocker oscillates around the eccentric center. During the injection period, the valve in the governor control unit is traveling in a downward direction. It is clear, therefore, that the more the governor turns the governor eccentric shaft in a clockwise direction, the lower will be the position of the annular groove with respect to ports *I* and *L* for a certain position of the crosshead, and the sooner the injection will be terminated. Finally, if the governor turns the governor eccentric shaft through the given angle so that the rocker center is moved down to the eccentric center, port *I* is already closed when port *F* in the pump unit opens and no fuel is delivered to the cylinders.

An instant after the injection has been terminated by the closing of port *I*, ports *L* and *D* will be put into communication by the annular groove so that all the fuel between the injection nozzle in the cylinder head and port *L* will be relieved of all residual pressure, and all after-drip from the injection nozzle prevented.

The gear in the pump unit is screwed into the crosshead and is always in mesh with the gear which in turn, is connected to the link by means of the bevel gears, shaft, and lever. By turning the lever, we therefore screw or unscrew the gear in the crosshead. If the gear is unscrewed, it will raise the plunger or valve *A* with respect to the crosshead, and since the beginning of injection was determined by the plunger or valve *A* on its downward stroke, the effect is to retard the beginning of injection. The lever and link in the pump unit are hooked up to the speed-control shaft in such a way that when the engine is slowing, injection will be retarded.

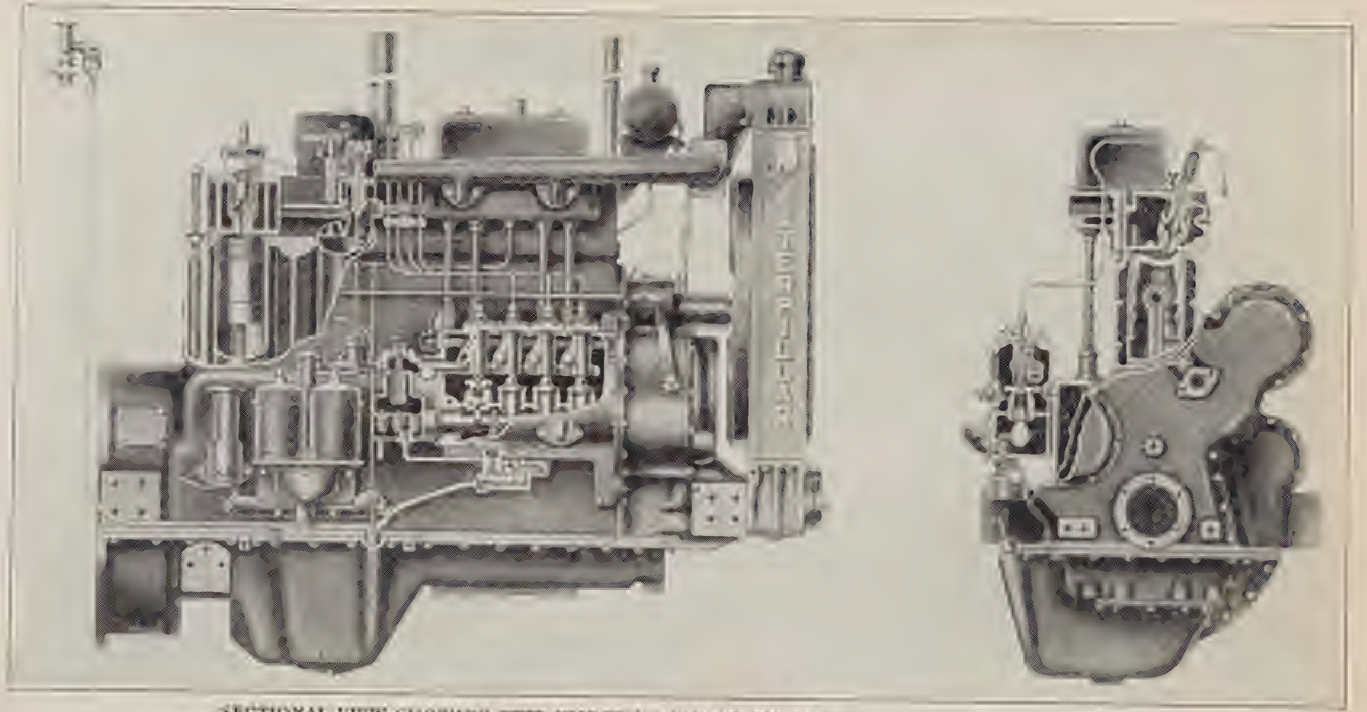
It is clear, then, that the beginning and termination of the injection process are determined by valves *A* and *K* respectively, and distributor valve *N* merely determines to which cylinder the charge is to be delivered. The amount of fuel and the time intervals between the opening of port *F* by valve *A* and the closing of port *I* by valve *K*, as previously explained, are under control of the governor by means of the governor eccentric shaft from a certain maximum fuel charge down to a point where no fuel is delivered.

In contrast to the individual-pump system where the injection pressure has to be built up within the pump and injection lines, this system merely sets the accumulator where fuel is stored under pressure in communication with the injectors. This results in a sharp commencement of injection irrespective of the load and speed at which the engine may be running. Similarly, at the end of the injection period this communication is suddenly cut off, and at the same time, the fuel lines are relieved of the injection pressure which results in a sharp cut-off without after-drip. Thus, all of the fuel is injected under proper pressure, and is well atomized, causing efficient combustion and clean exhaust.

Fuel Injector. The fact that the fuel lines are relieved of pressure at the end of the injection period makes it impossible for fuel to enter the cylinders except during the proper injection period, and makes it possible to employ the open-type injector. In this injector there are no needle valves that can stick and no adjustments of any kind. This system does not depend on the tightness of any valves for the prevention of after-drip.

The governor is built as an integral part of the Atimco injection unit, which results in close coupling without any exposed levers or links.

Timing Fuel Pumps. The methods of setting the Bosch and other pumps have been outlined. The only other detail is the ascertaining of dead center positions of the crank. These are almost invariably marked on the flywheel or gear wheel.



SECTIONAL VIEW SHOWING FUEL-INJECTION SYSTEM ON ALL CATERPILLAR DIESEL ENGINES

Courtesy of Caterpillar Tractor Co.

PART II

FUEL FOR HIGH-SPEED ENGINES

When Diesel speeds rose above 700 r.p.m., users discovered that the engine's performance was influenced by the character of the fuel used.

Various explanations were offered by experts in fuel engineering of why two fuels, whose chemical structures were identical, caused an engine's performance to vary. By some the difficulty was ascribed to "aromatic" hydrocarbons in the fuel. These "aromatic" molecules are those possessing more hydrogen molecules than are necessary to obtain a balance between the hydrogen and carbon atoms in the molecule. As a result, so the assumption runs, when the oil is injected into the engine a carbon particle breaking off from a "saturated" molecule (a molecule with the hydrogen and carbon atoms in a balanced condition) does not unite with oxygen in the air charge, but, instead, is seized by a "free" hydrogen atom in one of the "aromatic," or unsaturated, oil molecules. As a result, combustion does not process in a straightforward manner. The engine does not burn its fuel consistently and, in some cases, the combustion may be so inferior as to stop the engine.

Others have advanced the theory that a successful fuel oil must be a "straight-run," distillate, which has not been cracked to yield a maximum amount of gasoline.

Others take the view that the amount of carbon residue determines the engine performance. The claim is that slow-speed Diesels can burn an oil having 5 per cent carbon residue while high-speed engines should be supplied with an oil of less than 1 per cent carbon residue.

Combustion Knock. One of the objectionable features of many high-speed Diesels is a "knock," due, not to mechanical parts, but to combustion of the fuel oil. According to present view, combustion knock in a Diesel engine is caused by the accumulation of fuel in a cylinder prior to ignition. Even under conditions that insure ignition, the fuel does not ignite instantaneously but only after a definite delay. The longer this delay the more fuel accumulates in the engine, which then burns more or less simultaneously, accompanied by an audible knock. If the delay is extreme, the engine will fail to operate with the fuel.

It is significant that practically every factor which tends to aggravate knocking in a spark-ignition engine tends to suppress it in Diesel engines. Fuels of a paraffin base, consisting chiefly of saturated straight-chain hydrocarbons, give the smoothest combustion in Diesel engines, while naphthenes and aromatics burn roughly.

Ignitibility. There is a practical unanimity among Diesel engineers that ignitibility is a most decisive factor. Methods of ascertaining the relative ignitibility are both of the laboratory and test-floor types, although actual engine tests are viewed as the most satisfactory.

Tests. The success of the gasoline knock-testing engine, whereby gasoline is rated by its performance and given an "Octane Number," duplicating the performance of a test fuel composed in part of octane, encouraged the search for a method of determining Diesel fuel quality by its behavior in the engine itself.

A variety of methods have been used by LeMesurier and Stansfield, Boerlage and Broeze, and Pope and Murdock; in principle, however, all of these agreed. The "ignitibility" as such is not measured by any engine test, only determined indirectly on the basis of the behavior of the fuel in the test engine in regard to such characteristics as combustion knock, ignition lag, rate of pressure rise or ease of starting.

No matter what testing method is adopted for measuring ignitibility, it is essential to determine the manner in which the rating of the fuel shall be expressed.

One method, used for knock rating of gasolines, was proposed for rating the ignitibility of Diesel fuels, based on two standard reference fuels, one having a high, the other a low ignitibility. The test fuel was to be matched with a fuel consisting of the two reference fuels in such a proportion that its ignition quality (in the arbitrary scale of the test) would be equal to that of the test fuels. The rating of the fuel would be expressed, then, as the percentage concentration of the high-rate reference fuel.

Boerlage and Broeze proposed as primary standards, mixtures of cetene ($C_{16}H_{32}$) and alpha menthol naphthalene ($C_{11}H_{10}$). The cetene number in the specifications indicates the percentage of cetene in the reference fuel, a blend of cetene and alpha methyl napthalene, which has the same ignition characteristics as the fuel to be used in a particular Diesel. The engine builder will be in a position to state this value to the engine owner.

It is, of course, understood that engines having different designs of combustion chambers, different speeds and different compression pressures will require fuels with different cetene numbers. All of these factors influence the ignitibility of a fuel.

Aniline Number. Various tests have indicated that there is a definite correlation between the "Aniline Number" of a fuel and its ignitibility. This has been taken advantage of by Dr. A. E. Becker, who advanced a factor which he terms "Diesel Index." The expression is

$$\text{Diesel Index} = \frac{\text{Aniline Point (deg. F.)} \times \text{A. P. I. gravity}}{100}$$

Aniline Point is the lowest temperature at which equal parts of volume of freshly distilled aniline and the test sample of oil are completely miscible. It is determined by heating such a mixture in a jacketed test tube to a clear solution and noting the temperature at which turbidity appears as the mixture is cooled.

This test is indicative of the amount of paraffin-base oil in the test fuel. As has been stated previously, a straight paraffin oil gives the best results from an ignition standpoint, with an oil showing increased unsatisfactory performance as the percentage of paraffin decreases. Dr. Becker has shown that there is a close correlation between "Diesel Index" and "Cetene Number." On the other hand, certain petroleum technologists point out that the correlation is close only in a narrow range of cetene percentages, around 50.

It is the opinion of most engineers, who have studied the problem, that any one of the three factors may be employed, so that all three need not be included, in any specification. The "Diesel Index" is the easiest to discover, but many feel that "Cetene" is the best criterion of the three.

Viscosity. The viscosity, or "body," of an oil, as it is more generally understood by the average operator, is a measure of the relative fluidity at the temperature of observation. It can also be regarded as that inherent property by virtue of which flow is retarded, due to the resistance which the particles or molecules of an oil will offer to one another as they flow through the fuel system. It is possessed by all oils to a varying degree, according to their extent of refinement and source. Viscosity will vary inversely with temperature, that is, the colder an oil the heavier or more sluggish will it become.

Viscosity largely determines the degree of atomization experienced by the oil as it sprays out through the fuel-spray orifice. If sufficiently low at the pump's pressure, the oil stream will have a turbulent flow, consequently the oil particles will be broken up by their turbulent action. A more viscous oil will retain a non-turbulent flow at the same pressure, so will not possess much self-atomization characteristics. Atomization of the heavy oils must, then, depend upon centrifugal action of the nozzle, air turbulence or upon reduction of viscosity by heating the oil.

Carbon Residue. A certain percentage of a fuel may be incapable of evaporization and combustion. This includes any ash remaining after combustion of all organic substances and, likewise, those hydrocarbons and free carbon particles in the oil, which are non-combustible at working temperatures. Since most of this residue is carbon, it is customary to call it carbon residue, or Conradson carbon residue, after the name of the test equipment.

Theoretically, the Conradson test should be a guide to the amount of carbon and other non-combustibles in the oil. However, certain oils contain heavy gumming hydrocarbons which are impossible to burn in a Diesel cylinder. These will be driven off during the Conradson test, consequently an oil may show, say, 2 per cent Conradson while actually containing as much as 10 per cent of constituents impossible to be burned in the engine. At present many employ a modified Conradson test; the oil is heated and the vapor ignited. After the flame dies out, due to the absence of any more combustible vapor, the remainder in the crucible is termed carbon residue, and is always greater than the residue obtained by the Conradson test.

TABLE I
Diesel-Fuel-Oil Classification

Grade of Diesel Fuel	Flash Point Deg. Fahr.	Water and Sediment Per Cent by Volume	Viscosity—Seconds			Carbon Residue Per Cent by Weight	Ash Per Cent by Weight	Pour Point Deg. Fahr.	Sulphur Per Cent by Weight	Ignition Quality
			Saybolt Universal (at 100 F.)		Saybolt Furol (at 122 F.)					
	Min.[a]	Max.	Min.[b]	Max.	Max.	Max.	Max.	Max.[c]		
No. 1-D	115 or legal	0.05	32	50	...	0.2	0.02	35	[d]	[e]
No. 3-D	150	0.1	32	70	...	0.5	0.02	35	[d]	[e]
No. 4-D	150	0.6	..	250	...	3.0	0.04	35	[d]	[e]
No. 5-D	150	1.0	..	...	100	6.0	0.08	..	[d]	..
No. 6-D	Limits for No. 6-D fuel are the same as for No. 6 oil in the Tentative Specifications for Fuel Oils (A.S.T.M. Designation: D 396–34T) of the American Society for Testing Materials, unless modified by special negotiations between buyer and seller.									

[a] Minimum flash point, as stated or as required by local fire regulations, Fire Underwriters or state laws.

[b] For viscosities below 35 sec. at 100 F. Saybolt Universal, other methods than that by the Saybolt Universal viscosimeter at 100 F. may be used and the results converted.

[c] Lower pour points may be specified whenever required by local temperature conditions to facilitate storage and use, although it should not be necessary to specify a pour point of less than 0 F.

[d] So far as known, sulphur content need not be considered as regards combustion characteristics. However, when sulphur content is of consequence—as, for instance, in fuel for engines in intermittent service—the following limits are suggested:

Fuel No. 1-D......1.5 per cent max.
Fuel No. 3-D......1.5 per cent max.
Fuel No. 4-D......2.0 per cent max.
Fuel No. 5-D......2.0 per cent max.

[e] See Table II and discussion in Paragraph on "Ignitibility."

Viscosity-Gravity Number. Viscosity-Gravity Number was first proposed by Hill and Coats in 1928 as an indicator of an oil's value. A modification was later advanced by Moore and Kaye in 1934. The number is determined by the following equation:

$$G = 1.082\ A - 0.0887 + (0.776 - 0.72A) \times \log\ [\log\ (KV - 4)]$$

where G = specific gravity at 60°F.
A = viscosity—gravity constant
KV = kinematic viscosity in millistokes at 100°F.

Boiling-Point-Gravity Number. Boiling-Point-Gravity Number was first proposed by E. A. Jackson in 1935. Generally speaking, the larger the number, the more naphthenic the oil, and the lower the number, the more paraffinic the oil, and the better is its "ignitibility." The number is determined by the following equation:

$$G = A + (68 - 0.703A)\ \log\ B.P.$$

Where G = A.P.I. gravity in degrees
A = Boiling-point-gravity constant
$B.P.$ = 50 per cent boiling point on A.S.T.M. distillation curve, in degrees Centigrade.

The last two factors are not largely employed in fuel tests.

Various associations appointed committees in the past to investigate the subject and, finally, the American Society for Testing

TABLE II
Ignition Quality[a]

	Oil Grades		
	No. 1-D	No. 3-D	No. 4-D
Cetene number, min.........	50	40	30
Diesel index number, min....	45	30	20
Viscosity-gravity number, max.	0.86	0.89	0.91
Boiling-point-gravity number, max....................	188	195	200

[a] The values in Table II are equivalent within the limits of error of the test methods used. As the correlations between indexes and between any index and engine operation in the field are not completely established as yet, these values should be used in an approximate way only.

Materials prepared tentative specifications for several grades of fuel oils. The original specifications were recently altered and at present the specifications are as given in Table I.

Choice of Fuel. Broadly speaking, high-speed Diesels should be supplied with No. 1 fuel oil for best operating results. However, some types are able to use the No. 3 grade with success. These, generally, are those having a turbulence chamber or pre-combustion chamber. Such combustion devices seem to reduce ignition lag so can burn a poorer oil, or rather permit an early injection of fuel and limit the amount of oil ignited at any instant.

All Diesel builders are not in agreement as to the proper fuel characteristics. It will be seen from Table III that there is a wide range in all the factors. Many builders fail to even mention carbon residue and viscosity. Even in respect to ignition quality, few give a value, while several, those indicated by a numeral in the "Ignition Quality" column, expressed the following views.

(1) "If we do not have a large quantity of sediment left after the distillation test, we feel that the ignition quality will take care of itself."

(2) "Due to the unique design of the combustion chamber our engines will burn a wide assortment of low gravity, inexpensive fuels. It is not necessary to have any special fuels."

(3) "The supplier or distributor shall assume the responsibility of supplying a fuel oil of good ignition and burning qualities."

(4) "Our engine is not very sensitive to fuel. We have used almost all grades from kerosene to lubricating oil without loss in

TABLE III

Manufacturers' Recommended Specification Data for High-Speed (above 1000 r.p.m.) Diesel Engines

Engine Make	Viscosity S. U. @ 100° F. Seconds		Gravity °A. P. I.		Sulphur % Max.	Hard Asphalt % Max.	Conradson Carbon Residue % Max.	Ash % Max.	Water and Sediment % Max.	Flash Pt., °F. Min.	Pour Pt., °F. Max.	Heat Value B.t.u. /Lb. Min.	Distillation Characteristics			Ignition Quality Cetene Number Min.	Most Important Fuel Qualities		
	Min.	Max.	Min.	Max.									°F. 10%	°F. 90%	°F. EP		First	Second	Third
Direct-Injection:																			
1. Bronander	..	..	24	32	...	...	....	....	....	....	....	....	......	......	......	......	......	......	......
2. Cummins	34	..	26	36	1.0	1.0	....	....	None	....	....	....	460 max.	675 max.	......	(1)	Cleanliness	Viscosity	Dist. Residue
3. Fairbanks, Morse	..	200	30	40	1.0	...	0.3	....	1.0	140	....	18,500	......	630–660	......	......	Flash Pt.	Distillation	Heat Value
4. Guiberson	39	52	31	34	0.25	...	0.5	0.04	....	195	15	19,300	450–510	580–690	......	......	Ignition Quality	Cleanliness	Distillation
5. Monovalve	40	..	26	34	1.5	...	1.25	0.05	0.5	....	....	....	......	......	......	(2)	....	....	....
6. Stover	..	..	24	38	0.7	...	....	0.05	0.5	....	....	18,500	......	......	......	......	Ignition Quality	Comb. Residue	....
7. Sun-Junker	..	42	27	32	0.5	...	0.1	0.05	0.1	135	50	19,450	......	......	......	......	Ignition Quality	Viscosity	Cleanliness
8. Winton	30	100	26	34	1.0	...	10.0[a]	0.50	0.5	150	....	18,500	......	......	......	......	Flash Pt.	Viscosity	Cleanliness
Pre-Combustion:																			
9. Caterpillar	40	...	..	...	1.5	...	1.0	0.05	0.5	....	....	....	......	750 max.	......		....	....	....
10. Int. Harvester	35	100	24	...	1.5	...	1.0	....	0.5	150	....	....	460 max.	......	700 max.	(3)	Distillation	Cleanliness	Dist. Residue
11. Mason	..	...	27	30	Low	...	....	....	....	....	....	19,400	......	......	......	......	....	....	....
Turbulence-Chamber:																			
12. Continental	..	80	..	...	..	...	....	0.05	....	....	....	19,000	......	......	650 max.	(4)	Cleanliness	Ignition Quality	Viscosity
13. De La Vergne	40	60	28	...	1.0	...	0.5	0.02	0.5	150	....	19,000	......	700 max.	......		Ignition Quality[c]	Cleanliness[c]	Conradson Carbon[c]
14. Hercules	35	100	..	...	2.0	...	1.0	0.02	0.5	150	....	....	......	......	......	52"C.C.R."(5)	Viscosity	Ignition Quality	Cleanliness
15. National-Superior Co.	35	50	28	36	1.0	...	1.0	0.02	0.5	150	....	....	......	......	......	50	Ignition Quality	Hard Asphalt	Distillation
16. Waukesha (Comet)	32	80	..	...	0.7	...	2.0[a]	....	0.5	....	....	....	......	......	......	50"C.C.R."(6)	Viscosity[c]	Comb. Residue[c]	Ignition Quality[c]
Air-cell:																			
17. Buda-(M.A.N.)	35	40	26	29	0.5	...	0 03	0.02	0.2	150	0	....	98%	@ 700 max.	......	38–48	Ignition Quality	Cleanliness	Viscosity
Buda-(Lanova)	35	40	30	35	0.5	...	0.03	0 02	Trace	150	0	....	98%	@ 700 max.	......	46–60	Ignition Quality	Cleanliness	Viscosity

efficiency or power output. The engine is smooth and knockless with any of the fuels so far tried. We are having some sample fuels supplied with various ignition qualities, and tests will be run as soon as possible."

(5) "Refineries and oil distributing agents should assume the responsibility of supplying a fuel oil of good ignition and burning qualities. They can determine the ignitibility of their fuel oil by the use of a modified CFR engine. Recracked and recycled oils are usually not satisfactory—they are hard oils to ignite. The ignitibility of fuel oil cannot be determined by the usual characteristics of the physical state of oil such as gravity, viscosity, or color, except that oils of low viscosity and low A.P.I. gravity are indicative of a hard fuel oil to burn."

(6) "There is unquestionably a difference in the ability of various types of Diesel engines to handle fuels of low cetene value. For the present time, we feel that it is desirable to keep above 50 cetene; as our knowledge and experience increases, we may be able to lower this. Our cetene number determination is made by the critical compression ratio (C.C.R.) method and does not correlate exactly with ratings made by the delay period method."

In this tabulation the three columns under "Distillation Characteristics" give the temperature at which 10 per cent of the fuel will distill over, the temperature at which 90 per cent has distilled, and the temperature at which oil has distilled (this is the EP or end point).

Fuel Handling System. Regardless of where a high-speed Diesel is applied, there must be a fuel handling system. This must include a fuel tank, a fuel transfer pump, a fuel filter and the injection pump. Their several parts are shown in Fig. 42.

Supply Tank. The fuel-supply tank should contain as much oil as Fire Underwriters Rules permit. Frequently, this is limited to 200 gallons for storage within a building. In such event, an outside, larger tank must be added.

In filling a tank, the oil should be passed through a wire mesh filter in which rests a fibre lining.

The tank must have a vent, with its top provided with a standard "rain-proof" cap. A drain is likewise vital, so that water and sediment may be drained away.

This tank must not be set more than 6½ ft. below the transfer pump, see Fig. 42. If the pump is compelled to lift oil a greater height, the suction pressure may cause some of the oil to "gas," air-locking the piping.

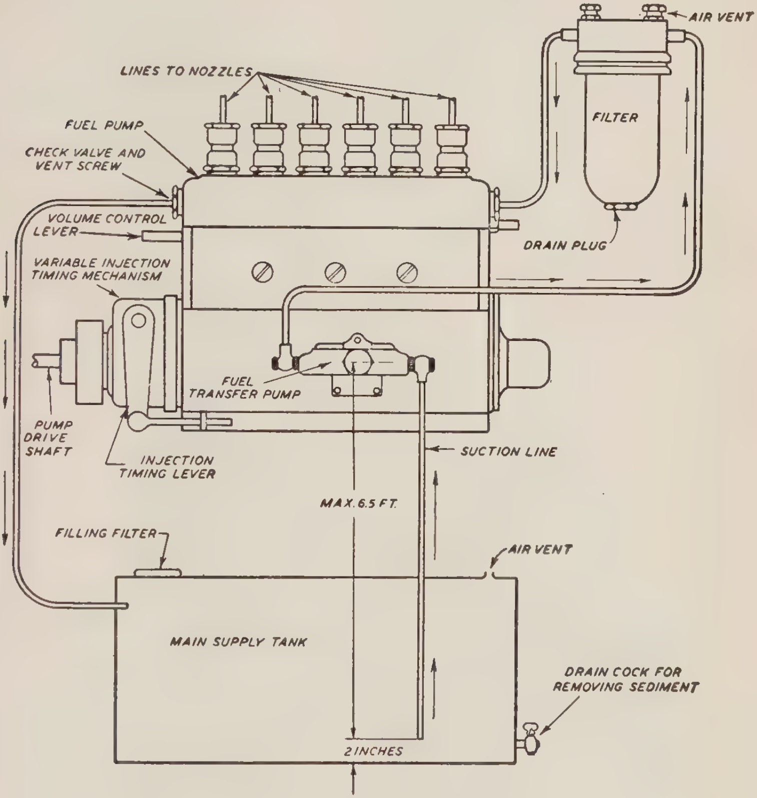


Fig. 42. Fuel Circulating System

Transfer Pump. The fuel-transfer pump in Fig. 41, is bolted to the body of the injection pump and is driven by the injection-pump camshaft.

As shown in Fig. 43, the transfer pump consists of a body containing a plunger which is provided with a spring and a rod whose roller contacts with the injection-pump cam (not shown).

The camshaft forces the roller, rod, and plunger to the right. Oil flows through the suction line and valve, into space. The spring forces the plunger to the left as soon as the cam leaves the roller.

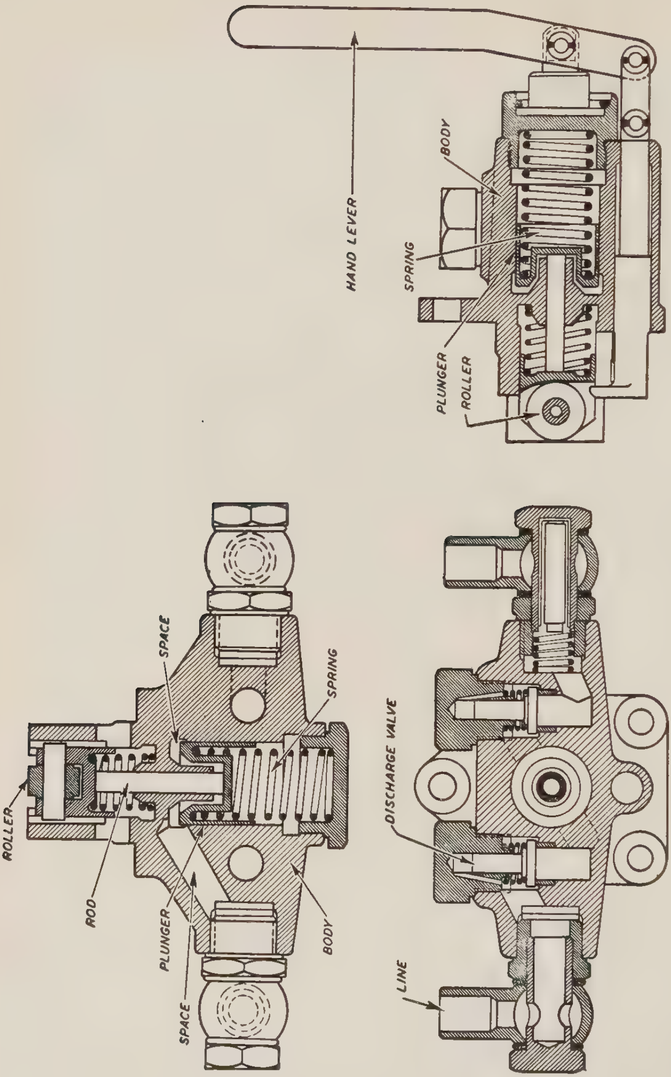


Fig. 43. Fuel Transfer Pump

The oil is then discharged through the discharge valve into the line leading to the fuel filter.

A hand lever is provided to enable the engineer to prime the piping. When starting an engine after a long shutdown, it is always advisable to hand-prime until oil shows at each of the cylinder injection-nozzle bleed-off valves.

Filters. A filter must be in the line ahead of the fuel-injection pump; otherwise dirt will damage the pump plungers.

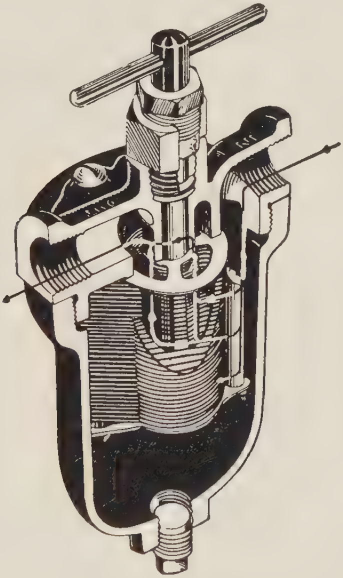


Fig. 44. Cuno Auto-Klean Filter
Courtesy of The Cuno Engineering Corporation

Two types of filters are found on high-speed Diesels, the "edge-type" and the "cloth-type"; both have favorable points and engine builders employ both.

One edge type filter is shown in Fig. 44. This filter is made up of a series of disks which are piled upon a central tube, and inserted in the filter case.

Oil enters the filter case and flows between the disks to the central tube and, then, out the outlet line. The space between the disks is exceedingly small, about 0.0003 inch, so dirt cannot pass but is stopped at the outer rim of the disk. To clean this filter, the set of disks is rotated by the handle lever at the top. In rotating, the disks rub against a scraper, which removes all the dirt resting around the outer edges of the disks.

The bag-type filter, Fig. 45, is simply a bag of close-mesh fibre. The bag should be of woolen yarn because cotton bags may allow the oil to pick up lint. These bags are cleaned by removing them and giving them a bath in kerosene.

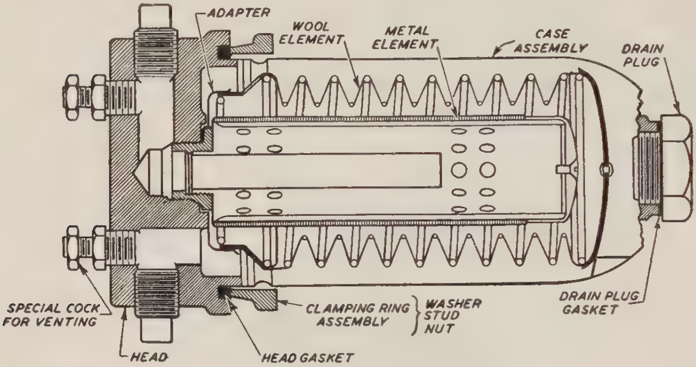


Fig. 45. Bag-Type Filter

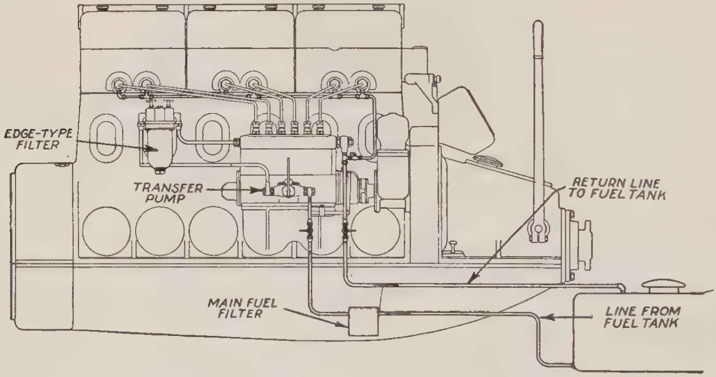
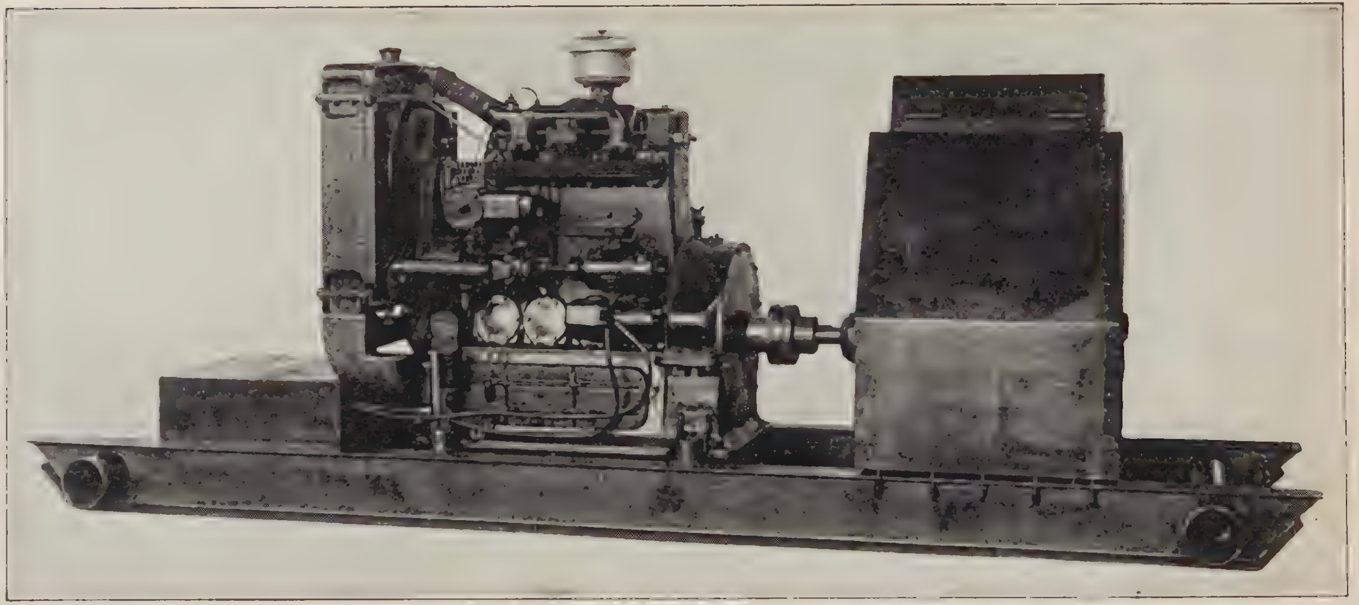


Fig. 46. Marine Fuel Oil Piping Diagram

Some engine builders use two filters, the first is an edge-type, with the woolen-bag filter between it and the injection pump.

Operators must clean the filters at stated periods. Otherwise, the collected dirt will stop up the filter and the transfer pump will build up a pressure in the oil line sufficient to wreck the filter.

In Fig. 46, a marine installation is shown, with the parts named. It will be seen that there is a main filter between the tank and transfer pump, as well as the edge-type filter in the discharge line from the transfer pump.



SHOWING THE OIL AND WATER PUMP SIDE OF THE 4-CYLINDER SUPERIOR DIESEL ENGINE, MODEL 1A-4, $4\frac{1}{2}$-INCH BORE, $5\frac{3}{4}$-INCH STROKE, 1200 R.P.M.

Courtesy of The Otto Engine Works
Division of The National Superior Co.

PART III

CUMMINS DIESEL

In its general lines of construction, the Cummins Diesel, Fig. 59, adheres closely to well-proven gasoline engine design. It is in the fuel handling and injection system developed by this company that the engine displays novelty, and, in contradiction to results obtained with most departures from standard practices, the Cummins injection system functions satisfactorily even at high speeds.

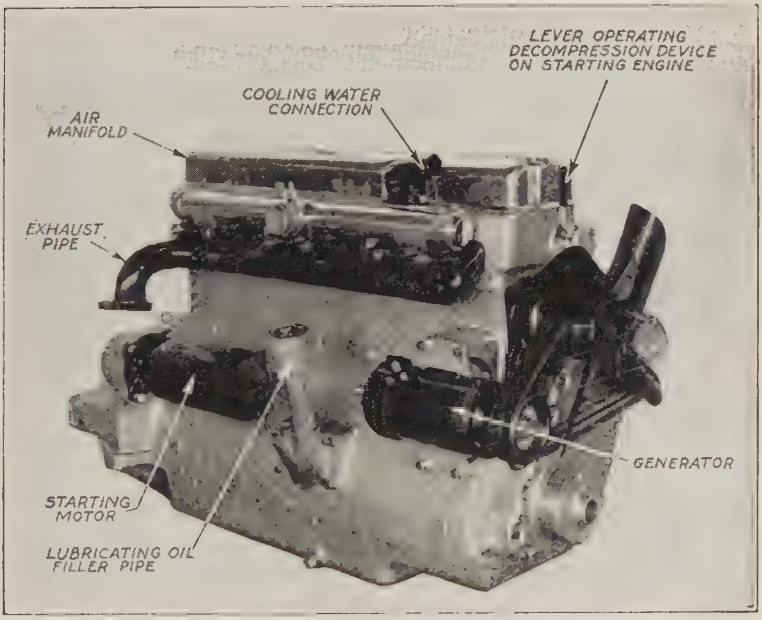

LEVER OPERATING DECOMPRESSION DEVICE ON STARTING ENGINE
COOLING WATER CONNECTION
AIR MANIFOLD
EXHAUST PIPE
GENERATOR
STARTING MOTOR
LUBRICATING OIL FILLER PIPE

Fig. 59. A Cummins High-Speed 2200 R.P.M. Diesel Developed from Automotive Gasoline Practices for Light Trucks. Weighs 6 Pounds per Horsepower

The crankshaft is underslung and at one end carries a gear which drives the camshaft, the fuel pump, the lubricating oil pump and the electric charging generator. The camshaft is located within the crankcase, similar to auto-engine practice, and its integral cams contact with rollers mounted at the end of short rockers, which in turn act on the vertical push rods. The push rods contact with the valve rockers, which are assembled on shafts mounted in a cast-iron open box forming the upper part of the engine.

The pistons, even in the highest speed engines, are of cast iron, and carry four compression rings and one oil ring. A full-floating piston pin is employed, held by a lock pin fitting into a groove on the pin. To lubricate the pin, the connecting rod is drilled, so that oil flows up from the crankpin bearing. The crank-pin bearing is a steel shell lined with babbitt while the piston pin bearing is a bronze bushing, as shown in Fig. 60.

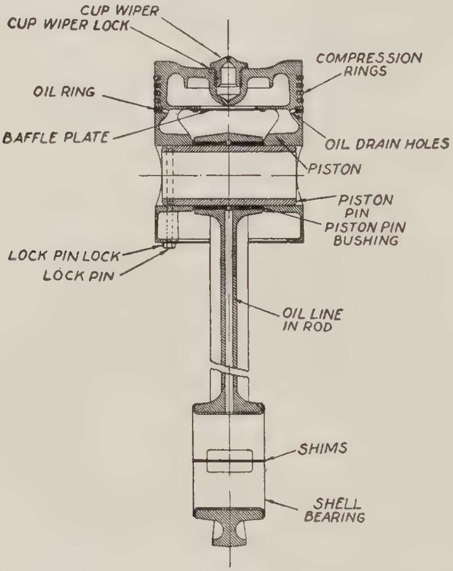


Fig. 60. Piston and Rod of Cummins Diesel

Camshaft Drive. The camshaft is located in the upper part of the crankcase, and is gear driven from the front end of the frame. No adjustment for timing can be made except by unmeshing the gears; this should never be done.

Valves. The inlet and exhaust valves seat directly upon the metal of the cylinder head. To regrind valves, the entire head must be removed. The valves have a 30 degree-angle seat and the seating surface need not exceed ⅛ inch wide. A clearance of 0.004 inch between valve rocker arm and valve stem is ample.

Crankshaft. The underslung crankshaft is supported in 7 bearings in the case of a six-cylinder unit and in 5 bearings on a four-cylinder engine.

The bearing shells are of steel lined with babbitt. The lining is so thin that in case of wear, new bearings must be installed.

To remove bearings, the cap should be removed and the crankshaft turned over by hand. This will cause the upper bearing half to rotate to a position where it can be removed. If it sticks, a small brass pin may be placed in the oil-feed hole in the shaft, with just enough protruding so that the end will catch the edge of the bearing and force it free when the shaft is rotated. Main bearing clearance, on the 4-inch shaft, should be around 0.007 inch.

Connecting Rod. The connecting rod, piston pin, and piston are shown in Fig. 60.

On the early Cummins engines (up to No. 9300), the crankpin bearing was formed in the rod itself. The babbitt was poured directly upon the bored end of the rod and upon the cap. Later engines have light steel bearings with a thin babbitted lining.

When wear occurs, scraping is not feasible and new bearings are necessary. However, a small amount of wear may be corrected by removal of the shims.

When new, the crankpin bearing should have a clearance in its bearing of 0.0035 inch. The side clearance is from 0.008 to 0.01 inch.

Piston Pin. The piston pin is held in the piston bosses by a long lock screw which rests in a groove machined in one end of the pin. The pin, then, can rotate both in the rod eye and in the bosses. The bosses, however, have no bearing bushings.

The piston pin bearing is a circular bushing with no provision for adjustment. The clearance should be approximately 0.003 inch, while the pin is fitted to the bosses so that it will just slip in, which means a clearance of about 0.0005 inch.

Piston. The cast-iron piston is fitted with three ⅛-inch wide compression, or "fire," rings and one $\frac{3}{16}$-inch oil ring above the piston pin bosses. The clearance between a ring and its groove should not exceed 0.005 inch.

Oiling System. Lubricating oil drips into the sump in the oil pan. From this point, a gear pump driven by the same shaft driving the fuel-injection pump, picks up the oil, forces it through a filter and into the pressure line. Oil under pressure is thinly fed to all the moving parts. A pressure of 45 pounds is maintained by means of a spring loaded piston which by-passes part of the oil; this regulation is placed at the end of the camshaft.

Fuel Oil. The Cummins Diesel will burn successfully either No. 1 or No. 3 A.S.T.M. Specification Diesel fuel oil.

In some instances, No. 3 oil will cause carbonization on the piston head. This occurs, mainly, when the load is variable, with half load or less present most of the time.

The vaporizer may, in this situation, show some carbon deposits, but as a rule, carbon settles in the vaporizer only when continuous full load conditions exist.

Fuel Pump. The fuel pump, Figs. 39 and 40, and governor assembly requires no special care or attention. It is automatically lubricated. It requires no adjustments and is built to last for the life of the engine. The governor is permanently set for the proper speeds of the engine and no adjustment or change should be attempted. Owners are urged not to tamper with the fuel pump or governor.

If, due to accident, the fuel pump or governor should cease to function, return it to the factory for repair. In the meantime, a loan pump or governor will be supplied by the factory upon receipt of a deposit. When the loan pump is returned to the factory in good order, the deposit is refunded.

If a fuel, which has sand or dirt in it, is used, the fuel pump distributor disks may become scored. These disks have a glass-like surface, and any scratch or scoring mark renders them unfit for service. Scored disks result in the engine smoking badly and in loss of power. These disks and covers are lapped on a special lapping machine, and should they become scored or damaged, they should be returned to the factory for reservicing. An exchange service is maintained on these disks and covers at the factory. Disks and covers damaged beyond repair, are not accepted on an exchange basis. Disks and covers must always be kept in pairs as they are not interchangeable.

Before removing the fuel pump disks, the pump should be washed clean on the outside with kerosene and a brush. After the pump is cleaned, remove the fuel lines going to the cylinders. They should be removed from the cylinder block to permit room to take off the disks.

When all the screws are removed, the disk covers should be slid off sideways, as the fuel between the disks causes them to stick together. These disks should never be placed with the lapped faces on any surface other than a clean cloth or sheet of paper.

Examine the disks and covers carefully, and if they show any scratches or scored marks, they should be replaced. Before reinstalling the disks and covers, they should be washed clean in kerosene and all holes blown out with air. Place the rotating disk in position over the three driving pins. (Note: This disk will only fit in one position and no mistake can be made in installation.) Oil the disk thoroughly with clean lubricating oil and place the cover carefully in place. Do not allow the corners of the disk and cover to nick or dent each other. A gasket of thin material, furnished by the engine builder, must be used between the cover and the case to prevent any leakage.

Press the cover down and start the cap screws. These must be screwed down one half turn at a time, going from one screw to another. This prevents distortion of the cover from the heavy spring pressure. Pull all cap screws tight and replace all fuel lines. Check all fuel lines carefully to see if they are running to the proper cylinder. All lines are numbered and should be placed on the proper pump connection. After the lines are reinstalled, it will be necessary to prime the engine.

Fuel Injector. It should seldom or never be necessary to completely disassemble a fuel injector, but if found necessary follow these given instructions closely.

Remove the two screws from the injector top housing.

Lift off the top housing and gasket, then remove the plunger and plunger spring.

With the injector body in a vise, remove the screw plug and its copper washer from the top of the injector. This plug is screwed in very tightly, and it may be necessary to use a small wrench on the shank of the screw driver to break it loose.

If the check valve seat is stuck, tap with a brass rod and hammer on top of the check valve seat stem to loosen.

With a screw driver, screw out the check valve seat stem which is to be found underneath the screw plug.

Then, remove the injector body from the vise and turn it upside down into the palm of the hand. The steel ball and its spring will fall into the hand. Should the spring fail to fall out when the injector is turned upside down, a small wire $\frac{1}{32}$ inch or under with a small hook on one end may be used to pull it out, taking care not to stretch the spring.

Injector Plunger. The injector plunger is a very close fit in the injector body and any attempt to change the size of the plunger or plunger hole will render it unfit for use.

Never ream or scrape the injector plunger hole.

Never use an emery cloth, sand paper or any abrasive in an attempt to reduce the size of the injector plunger or to increase the size of the hole.

Never clean the plunger or hole with anything harsher than a cloth.

Injector Cup. The injector cup assembly, Fig. 40, consists of the outer cup and a cone adapter, one fitting inside the other. The inner adapter is a ground fit to the outer cup and must hold both the fuel pressure and the combustion pressure.

The cone adapter seats on the end of the injector body. This seat is ground at the factory and if taken care of properly should last the life of the injector. Any small nick, dent or piece of dirt on this seat will cause it to leak and permit the fuel oil to flow up around the injector body and dilute the lubricating oil.

If the outer cup shows discoloration from heat above the tip, which extends into the combustion chamber, or the injector assembly sticks when being removed from the head, the seat between the outside cup and the head is leaking. If this seat leaks and blow-by is permitted, the injector cup will become so hot that the fuel will carbonize and the spray holes will stop up. Make sure both the cup seat and the seat in the head are clean.

If the fine fuel spray nozzles of the injector cup should become clogged or the spray holes obstructed, it is usually caused by improper setting of injector plungers, dirt in the fuel or operation of the engine at overload or an overheated engine. A cup cleaning kit is furnished, consisting of a file card brush with two openings in the end of the handle in which will be found a small drill, several very small wire drills and a drill vise for these small drills.

(1) Hold the injector in the left hand, as it is taken from the engine. Clean the cup by brushing lightly with the brush, as shown at 1 in Fig. 61. Do not use a file or emery cloth.

(2) Hold the outer cup, as shown at 2, upside down, when using the large drill in order that any foreign matter may fall out of the cup. Never use a drill other than the one furnished by the engine builder for this purpose. This drill point is ground to the correct contour to fit the hole in the cup.

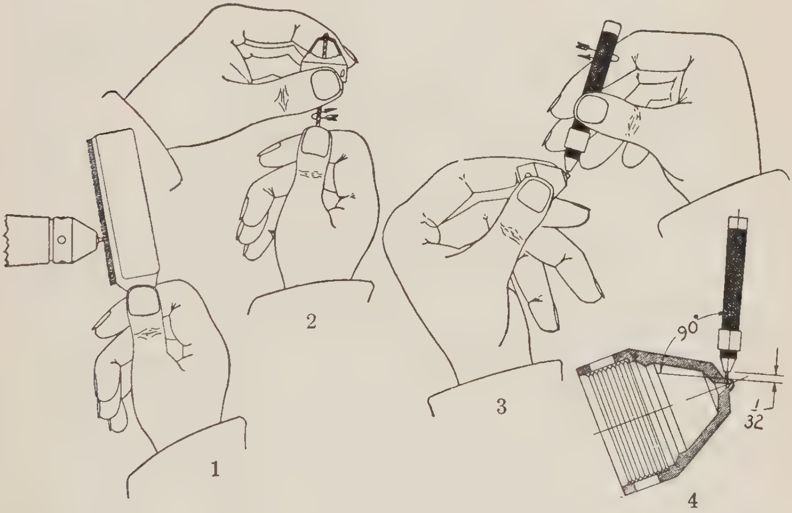


Fig. 61. Cleaning Cummins Vaporizer

(3) When cleaning the small spray holes, have the small wire drill project not more than $\frac{1}{32}$ inch from the holder. Apply the small wire drill at the angle shown in positions 3 and 4 of Fig. 61. Be sure there are no burrs on the end of the drill; otherwise it will not enter the small holes in the cup. Never use drills other than those furnished by the builder as a .001 or .002 of an inch variation in the size of the wire will cause improper engine performance.

The small holes in the small adapter, or inside cup, should be cleaned with the small drill furnished in the cleaning kit. These holes are fuel passages and if allowed to carbon up, will cause a falling off in power. The small groove in the seat of the cup should be kept clean, but the seat against the body must not be scratched or fuel will leak past the cups, causing dilution.

After cleaning an injector cup, fill it with clean fuel and blow the fuel through the spray holes. Each spray should spurt out in the proper direction, and at the proper angle, making a balanced pattern. If one of the sprays should be deflected, the hole should be recleaned. Deflection of a spray causes it to strike against the cylinder wall or cylinder head, where it condenses and will not readily burn, because it will not be in fine particles with each particle completely surrounded by air.

PART IV

FAIRBANKS, MORSE HIGH-SPEED DIESEL

The high-speed Diesel, Fig. 62, built by Fairbanks, Morse & Co. is obtainable in two cylinder bores and strokes, namely, $4\frac{1}{4}$ x 6 inch and $5\frac{1}{2}$ x $7\frac{1}{2}$ inch. The smaller bored engine is rated at 10 horsepower per cylinder at 1200 r.p.m. The $5\frac{1}{2}$ x $7\frac{1}{2}$-inch cylinder is rated at 20 horsepower per cylinder, with four cylinders, the smallest number offered in a unit, giving a rating of 80 horsepower at 1200 revolutions per minute.

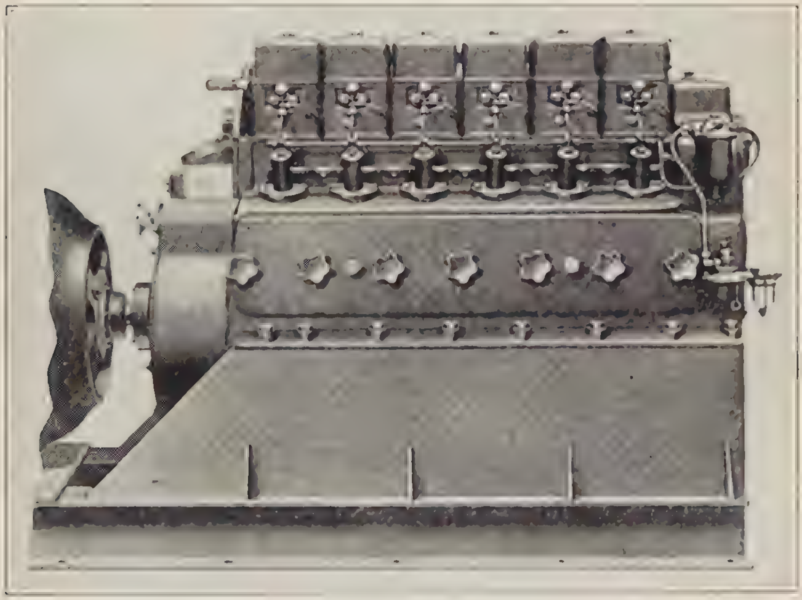


Fig. 62. Fairbanks, Morse & Co.'s High-Speed Diesel with Generator

Frame. The crankcase and cylinder block is a one piece casting of nickel-alloy cast iron. In the block, are inserted the "wet" cylinder liners. Each is sealed at the lower end by a rubber ring and at the top by a copper gasket.

Cylinder Heads. The cylinder heads are cast separate, one for each cylinder. The head contains one exhaust and one inlet valve which seat directly on the cylinder head metal. A removable guide insures the correct position for the valve.

Valve Gear. The camshaft is located in the upper portion of the crankcase, Fig. 63, and is driven from the crankshaft by a chain drive. Each cam is milled on the one-piece camshaft, so that no change in valve timing is necessary or possible.

The standard valve timings are:

Exhaust Valve

Opens: 64½ degrees before bottom dead center
Closes: 18½ degrees after top dead center

Inlet Valve

Opens: 22 degrees before top dead center
Closes: 18½ degrees after top dead center

It will be noticed that these settings cause a considerable overlap, at which time both the exhaust and inlet valves all open.

Push rods passing up through the block casting actuate the valves through rocker arms.

Rocker Clearance. Only after a valve has been reground will the clearance between the push rod and rocker arm, or between the rocker arm and valve stem vary. When the engine is cold, these clearances should be set at from 0.012 to 0.015 inch. When the engine becomes hot, these clearances should be reduced to 0.008 inch for the inlet valve and 0.012 inch for the exhaust valve.

Fuel System. The Fairbanks, Morse Diesel embodies a turbulence chamber in the cylinder head. Probably, the action somewhat approximates that of a pre-combustion chamber, for part of the air charge is retained in the clearance between piston and cylinder head.

The fuel-injection pump is of Bosch make, with a separate pump unit for each cylinder. These pumps are placed at an angle in the side of the crankcase. This enables the discharge end of the pump and the piping to be outside the frame. Cams on the camshaft contact with the plunger guides. It will be noted that in this engine a rocker is interposed between the cam and fuel pump plunger; this enables the injection timing to be delayed in starting.

The spray valve which enters the turbulence chamber in the

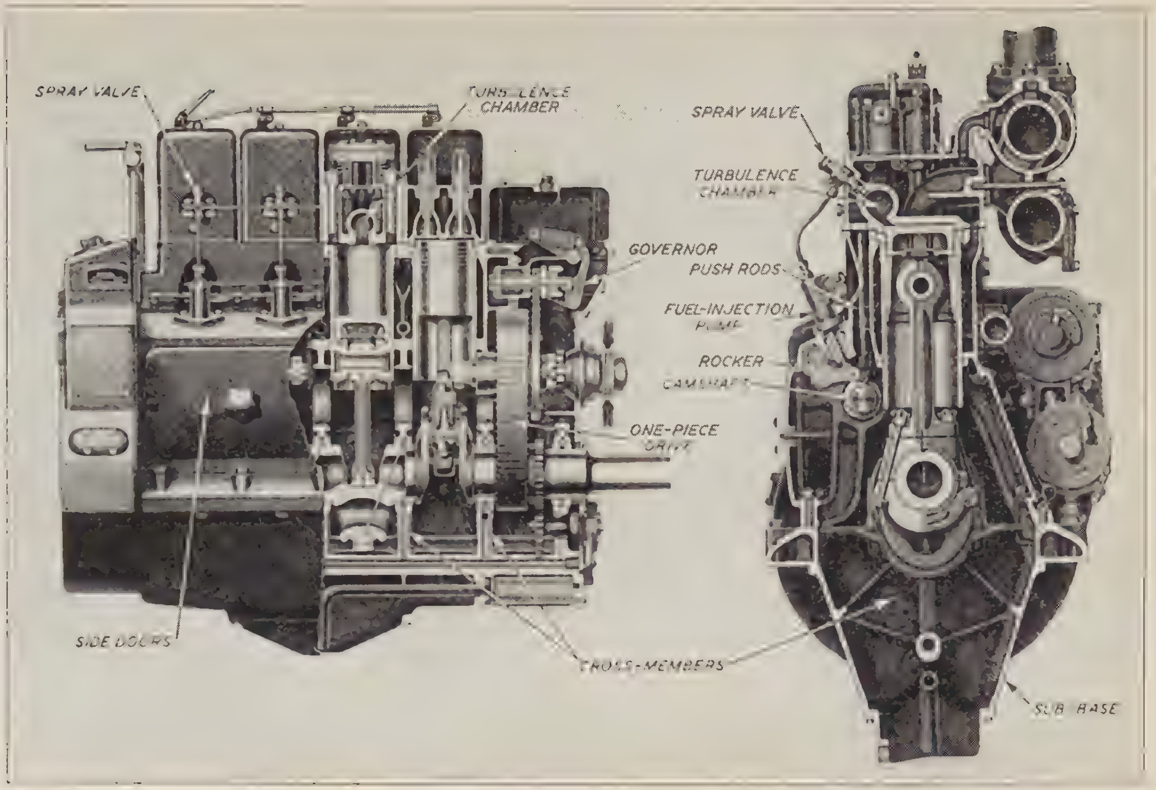


Fig. 63. Section through Fairbanks, Morse & Co.'s Four-Cycle Diesel

cylinder head is the Bosch spring-loaded, differential-needle, pintle type.

Governor. The governor, of centrifugal flyball type, is driven from the camshaft by a helical gear. The governor sleeves acting through a rocker arm, shift the control shaft of the injection pumps. A heavy spring counteracts the centrifugal force at full speeds. When idling, this spring is free and a light spring on the pump shaft gives the idling speed control.

Injection Timing. The pump is set to start its delivery stroke 69 degrees before dead center. However, the actual time the fuel sprays into the combustion chamber is much later, due to pipe expansion and the time required for the pump plunger to cover the pump suction port.

Main Bearings. Unlike most high-speed Diesels, the Fairbanks, Morse engine does not have underslung main bearings. Instead, heavy-duty practice is followed by placing the shaft in bearings seated in the cross-members of the sub-base.

Access to these bearings is through large side doors on the crankcase.

When the cap and upper half of a bearing is removed, the lower bearing half can be rolled out by rotating the shaft.

The bearing shells are of steel and the babbitt lining, which is centrifugally cast, is thick enough to be scraped.

Bearing Clearance. The clearance between shaft and bearing should be from 0.001 to 0.003 inch. The end clearance, that is, the clearance between bearing end and the crank-throw should be from 0.008 to 0.010 inch.

Connecting Rod. The heat-treated steel connecting rod has a marine type crankend, such as is found on large Diesels. The end of the rod forms a tee, and the two halves of the crankpin bearing are held to this tee foot by two bolts. It will be seen from the illustration that these bolts are at an angle, which permits the use of a large bearing, and a rod foot small enough to pass through the cylinder bore during disassembly.

Crankpin Clearance. When the crankpin bearing has been in service for sometime, wear increases the clearance and this must be brought back to the original value.

The clearance should range from 0.001 inch to 0.003 inch.

The end play should not exceed 0.008 inch nor be less than 0.004 inch. While the clearance may be checked by placing lead wire across the pin and tightening up on the bearing, a reasonably practical method is to place the piston at top dead center and see if the crankpin bearing will move slightly when a bar is placed below it. Noticeable movement denotes excessive clearance.

Piston Pin. The eye end of the connecting rod carries a bushing for the piston pin bearing. The pin rests in bosses in the piston and is free to rotate in these bosses. In other words, it is "full-floating," but most of the rotation is in the rod bushing. Snap rings fit into grooves in the piston at the inner ends of the bosses, so the pin cannot strike the cylinder wall.

To remove a pin, after the piston and rod have been withdrawn from the cylinder, one of these snap rings is removed with a long-nose plier. This then permits one to push the pin out of the bosses and rod.

The piston pin bushing should have a clearance of from 0.0005 to 0.0015 inch. If badly worn, the dowel holding the bushing is removed and the bushing driven out of the rod eye.

When inserting a new bushing, due care must be exercised to have the oil hole in the bushing align with the hole in the drilled rod. A new hole must then be drilled in the bushing to accommodate the dowel. The latter prevents the bushing from shifting.

The piston pin ends should have a clearance in the bosses of 0.001 inch or less.

Piston Rings. Six rings are used per cylinder; one of these is an oil-scraper ring.

Ring side clearance should be just enough to permit the rings to move in and out. If a ring becomes stuck, it must be freed. If this requires its removal from the piston, the ring will be over stressed and must be replaced by a new ring.

Cylinder Liner. The clearance between piston and liner should approximate 0.005 inch. Of course, much more clearance is permissible before a liner need be replaced.

Piston Head Clearance. There is only $\frac{1}{16}$-inch clearance between the piston top and the cylinder head. If more than this, the compression pressure may become too low to cause final ignition. This clearance can be measured by removing the cylinder head and placing two lead wires on the piston crown. The head is then replaced and the shaft turned until the piston reaches and passes top dead center. Removal of the head will enable the engineer to "mike" the lead wires.

This clearance may be adjusted by adding or subtracting shims from between the foot of the connecting rod and the crankpin bearing.

Lubricating System. A pressure oiling system distributes lubricating oil to all the parts. Splash from the crankarms insures an oil film on the cylinder walls.

A rotary pump at the end of the camshaft draws oil from the crankcase sump, passes it through a filter and to the pressure manifold.

Cooling Water. *Circulating* water from the jackets is handled by a rotary pump driven from the camshaft; in the marine engines, a plunger pump is used.

Starting. To start the engine, a lever is shifted to put the fuel-injection pumps into the "fast" position. This closes the electric circuit to the starting motor. If the engine does not start firing at once, the fuel pumps may be air bound. As soon as the engine comes up to speed, the control lever is shifted to the "run" position.

PART V

WINTON DIESEL

The Winton two-cycle, 8-inch bore by 10-inch stroke, high-speed Diesel, Fig. 102, while built in the plant of the Winton Engine Corporation, is the design product of the General Motors Research Laboratories. At 720 r.p.m., the 8 x 10-inch cylinder is rated at 75 horsepower. The motive for the development of the engine was the railway locomotive business. The General Motors executives realized that the advent of the Diesel electric switching locomotive in 1925 was but the forerunner of an extensive Diesel program in railroading.

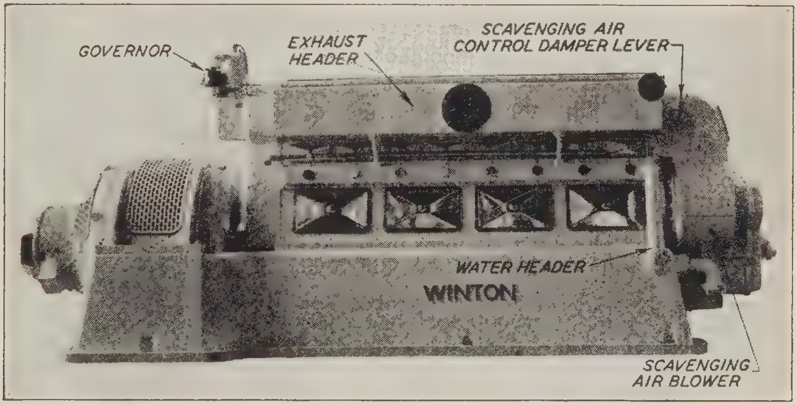


Fig. 102. Winton Two-Cycle 8-in-line High-Speed Diesel

While the present design of this engine will probably be radically altered within two or three years, it has captured the rail-car and mainline locomotive fields. The engine is also built in the V-type as in Fig. 103.

Frame. The framing of the Winton Diesel differs from all other designs. Essentially, the frame of the 8-in-line engine, Fig. 102, consists of a series of vertical struts, to which are welded side, end, and top plates. One of these frame members, Fig. 104, is placed at each end of the engine frame and one between each pair of cylinders.

Heavy plates are welded to the sides, as is the case at the ends. In addition, the top plate, which has had recesses cut in it to accommodate the cylinder liners, is shaped to form a trough for the camshaft. The final frame is shown in Fig. 105.

Cylinder Liners. This frame carries the cylinder liners and rests upon a steel sub-base, as shown in Fig. 102, which supports the shaft bearings in cross girders. The clearance to be maintained at the main bearings is 0.006 to 0.008 inch.

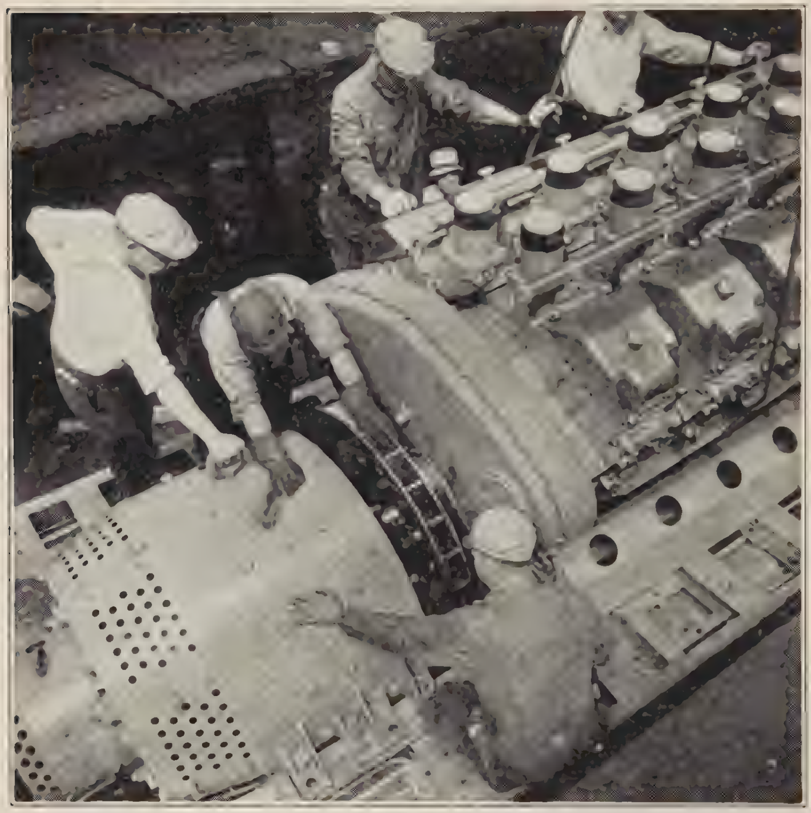


Fig. 103. Winton 16-Cylinder, Two-Cycle V-Type, High-Speed Diesel

The cylinder liner is unusual. This liner is a double-wall sleeve with the cooling water flow in the cavity between the two walls. Fig. 106 shows, diagrammatically, the liner construction.

The uniflow 2-cycle principle embodied in this 8-cylinder Win-

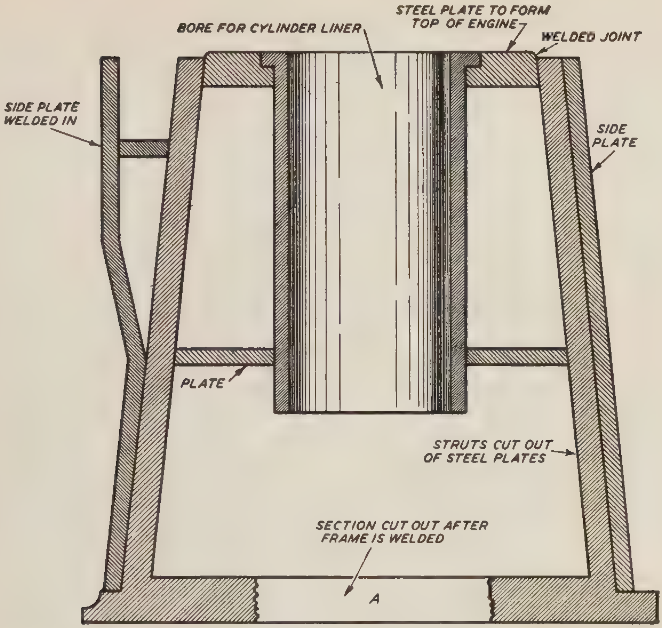

STEEL PLATE TO FORM TOP OF ENGINE
BORE FOR CYLINDER LINER
WELDED JOINT
SIDE PLATE WELDED IN
SIDE PLATE
PLATE
STRUTS CUT OUT OF STEEL PLATES
SECTION CUT OUT AFTER FRAME IS WELDED
A

Fig. 104. Diagram of Frame of Winton Diesel

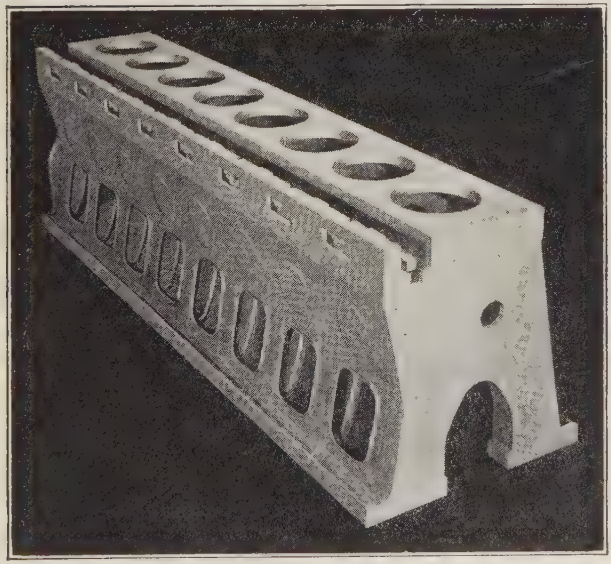


Fig. 105. Welded Steel Crankcase on Winton Diesel

ton Diesel, removes the usual 2-cycle limitations of port scavenging and exhaust, and by providing practically perfect scavenging, greatly increases efficiency. Instead of employing the usual 2-cycle method of scavenging, known as "loop scavenging," this new principle permits the exhaust gases to pass out through valves in the cylinder head, as in a 4-cycle engine.

Ports for air scavenging, $1\frac{29}{64}$ inches high, are cast in the liner at the bottom end of the piston stroke, so that the scavenging air flow starts when the crank is 51 degrees ahead of bottom dead center, or $22\frac{1}{2}$ degrees after the exhaust valves open. Since there are no exhaust ports, the scavenging ports fill the entire periphery of the cylinder, thereby insuring ample air flow at low velocity. The air passage to the ports is made up of the spaces between the cylinders and the plates of the framing.

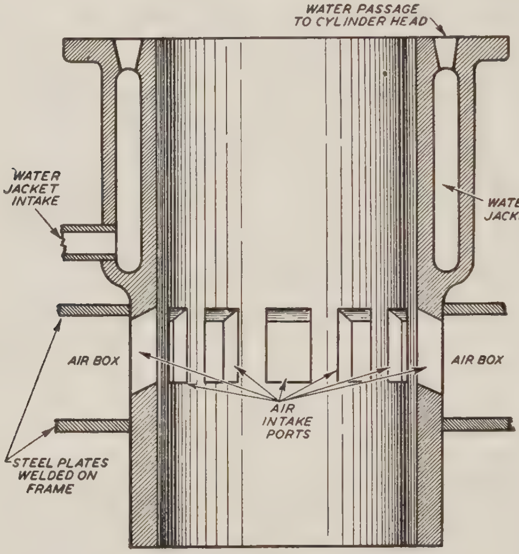


Fig. 106. Schematical Outline of Winton Liner and Cylinder Jacket

As soon as the exhaust valves open, the cylinder pressure is greatly reduced, facilitating entry of scavenging air when the scavenging ports are opened, so that when the scavenging air is forced into the cylinder by a blower, the air flows through the cylinder in a single direction and out the exhaust valves in the head, expelling any remaining exhaust gases.

Air for cylinder scavenging is supplied at 3-lb. pressure by a rotary three-lobed blower mounted on the engine framing and driven directly from the crankshaft. These blower lobes are helical in outline, which increases the volumetric efficiency. The blower displacement is 1.64 times the total engine-cylinder volume.

The engine's compression ratio is 16, giving a 550-lb. compression end pressure, with a peak combustion pressure of 825 pounds.

Clearance between piston skirt and liner is 0.008 inch but even at 0.02 inch the blow-by is small.

The cylinder size of 8-inch bore and 10-inch stroke gives 75 horsepower per cylinder at 750 revolutions per minute.

Cylinder Heads. Five valve openings are provided in the cast-iron cylinder head. Four of these, for the exhaust valves, are placed symmetrically around the central fuel-valve opening. Ample cooling space is provided between these valves. Exhaust valves are 2.77 inches in diameter, and due to the area provided by the four, have a lift of but $\frac{9}{16}$ inch.

Cams on the overhead camshaft operate the two rockers for these four valves, the rockers being steel plates press-fitted on to a steel collar used as the fulcrum pin bearing. To eliminate noise that occurs when cams strike the rocker arm rollers, the rollers on the engine are provided with a roller clearance take-up, so that a roller is always in contact with its cam. The clearance between the rocker arm and valve stem is 0.003 inch.

Fuel-Injection System. Of special interest is the fuel pump and spray valve. These devices are almost always separate units in engine designs. For the Winton engine, the designer incorporated both pump and spray valve in a single assembly bolted to the cylinder head, and this design comprises what is known as the "unit injection system." This arrangement eliminates all surges in the fuel pumping, and since the oil line from the oil transfer pump is under but 25-lb. pressure, piping fractures are absent.

The injection mechanism is shown in Fig. 107. Oil is delivered by a low-pressure rotary pump, and enters the fuel-pump body at the tube. It flows down the tube and comes to rest in the cavity. This cavity communicates with the pump barrel through two ports. The second port is provided with a spring which encircles the barrel so that oil and air may pass *out* the pump barrel into the cavity but cannot pass from the cavity to the barrel of the fuel pump.

The fuel-pump plunger has two helices, and its shank has a hexagon-shaped section which passes through a bushing. As shown at the right of Fig. 107, this bushing has its outer surface cut to form a pinion. This pinion is in mesh with a rack. This rack is linked to the governor, which moves the rack to the right or left, which causes a rotation of the bushing and, consequently, of the pump plunger.

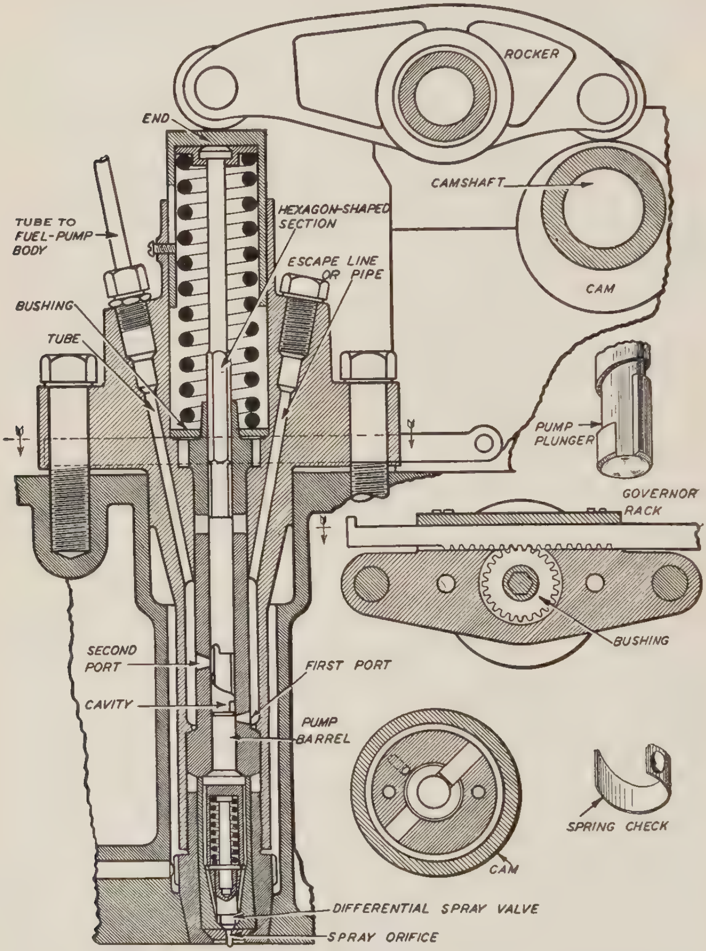


Fig. 107. Pump and Nozzle of Winton Two-Cycle Diesel

The camshaft is driven from the engine shaft by a chain drive. When the high portion of the cam comes under the roller of the rocker, the end forces the fuel-pump plunger downward. Previously, a flow of oil through the tube has filled the cavity, and through the first port, and the pump barrel.

As the fuel-pump plunger is forced downward, oil in the pump barrel is forced back out through the first port into the cavity, until the end of the fuel-pump plunger covers the first port. The continued downward movement of the fuel-pump plunger displaces more of the oil in the barrel, which escapes through the second port until the full-section of the pump plunger covers this port. The pump plunger then raises the pressure on the oil left in the barrel until the pressure reaches around 5000 pounds. When this occurs, the resistance of the spring of the differential spray valve is overcome. The valve then lifts, and the plunger forces the oil through the spray orifice into the engine cylinder.

This spray action continues until the helix of the plunger uncovers the first port, whereupon the oil starts to flow back into the cavity, and spraying into the cylinder ceases.

At a change in engine speed, say, at an increase in speed, the governor shifts the governor rack to the right, which causes the pump plunger to rotate so that the helix uncovers the first port earlier, and so reduces the oil entering the engine cylinder.

It will be seen that injection starts when the top helix covers the second port and stops when the lower helix uncovers the first port. Both start, and the end of the injection is under control.

The spring check permits oil and air to pass out the pump barrel but prevents oil entering the barrel from the cavity. The use of two ports was intended to free the pump of air, for any air passing out through the second port is free to pass up through the escape line or pipe. In operation, air binding did occur, so it was necessary to connect the escape line or pipe to the oil-handling pump suction, thereby causing the oil to circulate continuously through the pump casing, and carry all air with it.

The spray nozzle carries six 0.010 inch holes, set at angles of 75 degrees with the cylinder axis. Injection of fuel occurs at 7 degrees before top dead center. The pump timing, if it is to be changed, must be set by use of an indicator diagram.

In service, change of timing is seldom necessary. All the operator need do is to see that the clearance between valve cap and rocker roller is 0.003 inch when the engine is warm.

To obtain balancing of the load on the several cylinders, that is, to obtain equal exhaust temperatures, slight change in timing of a pump is possible by a micrometric adjustment on the end of the governor rack.

Pistons. The pistons are of aluminum alloy, weighing less than 87 pounds, each. Each piston carries 5 snap rings and one oil control ring.

Connecting Rod and Pins. The connecting rod is a steel forging, with the lower end of the marine type. The crankpin bearing is steel casting into which is cast, centrifugally, a high-lead bronze lining, of standard design. Clearance between crankpin and bearing is 0.006 inch.

A feature of the rod is that the piston pin end carries needle, or roller, bearings, which separate the rod bushing and the full-floating pin. The full complement of small rollers have a much greater carrying capacity than any other type of bearing. No cages are employed, and the needles contact with each other.

No anti-friction metal is used on the upper end of the connecting rod; the rod bushing is of steel, ground. This pin is free to float in the piston bosses, in which it has a sliding fit, about 0.0005 inch clearance.

To lubricate the pins, a pressure oiling system is employed. This oil reaches the piston pins through the drilled rod. Oil passing up through the drilled rod serves another purpose. The end of the rod has several drilled passages leading from the bearing sleeve. Oil flows through these holes and sprays out upon the lower side of the piston crown, which serves to keep the aluminum casting cool.

TRUCKS

Improved roads and the development of the truck have made possible the transportation of freight and materials over routes not well covered by railroads both in less time and at less cost. Prior to the development of hard-surfaced and marked highways, the truck industry was largely concerned with equipment suitable for short hauls where speed was a secondary consideration, although it was even then faster than the horse-drawn vehicle. With the development of the trucking industry, manufacturers have kept pace by increasing sizes and body styles to meet the various demands and requirements of the buying public, until at the present time trucks are being made which satisfy certain specific requirements as to the shape and size of body and have speeds quite comparable to those of the automobile.

Trucks vary in size from the small automobile with the "pick-up" box on the rear to the large transport trucks capable of hauling many tons. Ordinarily the size of the truck is determined by the use to which it is put and its load capacity, measured in tons or fractions thereof. Special uses make it imperative that certain features be developed which are not found on the average truck. For instance, trucks designed for the house to house delivery of bottled milk are equipped with dual controls in order that the delivery man may drive from either side and serve customers on both sides of a street at the same time. Bodies have almost as many shapes and sizes as there are uses to which the truck is to be put.

MECHANICAL DETAILS

Inasmuch as trucks are a product of the automobile industry, their construction is fashioned along the same general lines. Some modifications are necessary, however, to meet the varying requirements as to power, load, speed, etc.

Engines. Truck manufacturers have adopted the four-stroke cycle engine as the most efficient and reliable type for truck use. While it was at one time thought that four cylinders were a sufficient number for heavy-duty work, the trend is now toward the six and

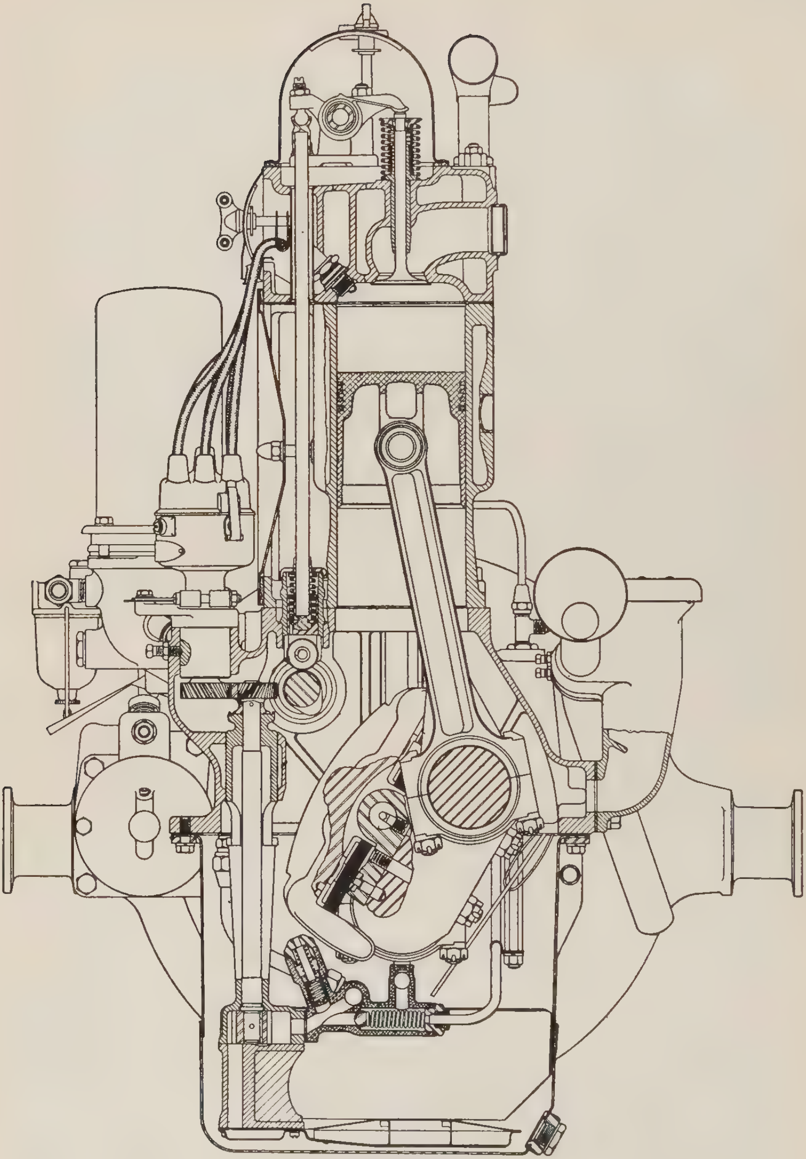


Fig. 1. Overhead Valve Truck Engine

eight. The valve-in-head, Fig. 1, L-head, Fig. 2, and "V-8", Fig. 3, are all satisfactory designs for use in heavy hauling. Recently there has been a development of the horizontal type, Fig. 4 showing one of this type with crank-case cover removed. This engine may be mounted on the chassis under the load or cab, thus materially increasing the size of the available space for the body, and therefore the pay load that can be hauled. Accessibility to some motor parts must of necessity be sacrificed, but this point is of less importance than formerly, due to improved design and better materials and workmanship that go into the modern engine.

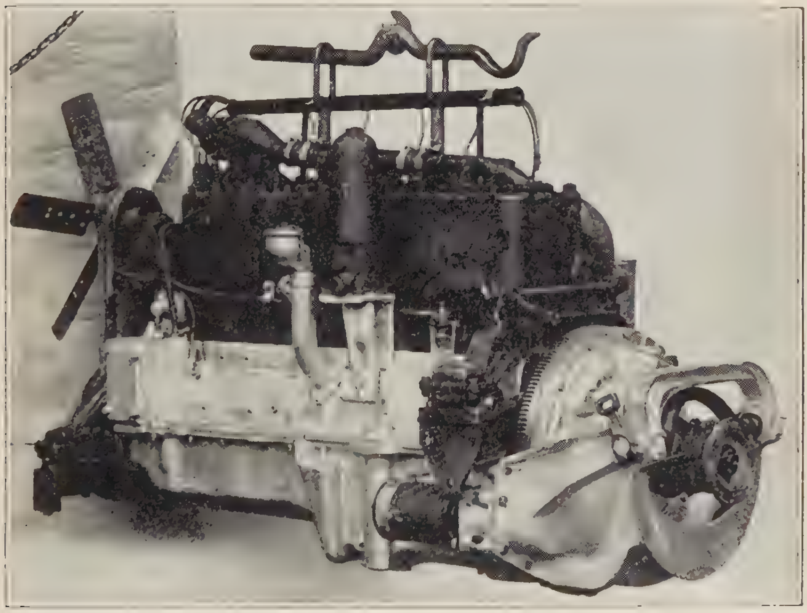


Fig. 2. L-Head Truck Engine

Vertical engines are also sometimes placed under the cab, where minor adjustments may be made by removing a cover, or by sliding the engine forward on rails. Motor construction follows in a general way the practices found to be fundamentally sound in the automobile field, with the possible exception of more rugged construction and somewhat greater tolerances to take care of the heavier pulling encountered. Crank shafts are usually counterbalanced, as

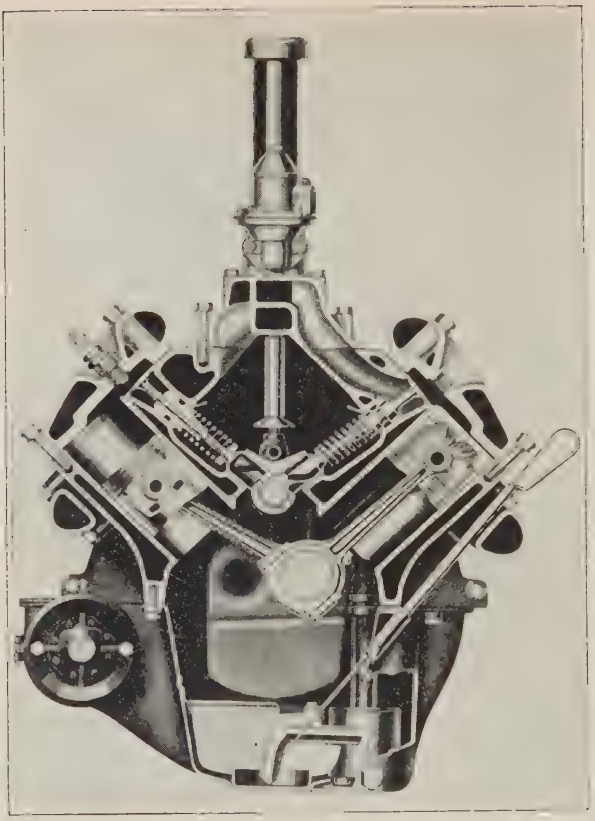


Fig. 3. Ford "V-8" Engine

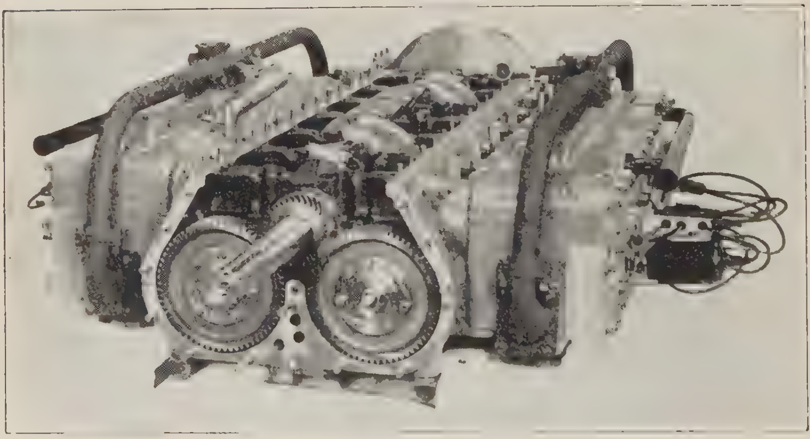


Fig. 4. White Pancake Type Truck Engine

shown in Fig. 5. Lanchester or harmonic balancers, Figs. 6 and 7, respectively, smooth out torsional vibrations. Construction of cam shafts follow the general design of the automobile engine with the exception that the shape of the cams may vary somewhat. Truck engines are designed for heavy-duty work and hence are capable of developing a large torque over a considerable range of speed. It

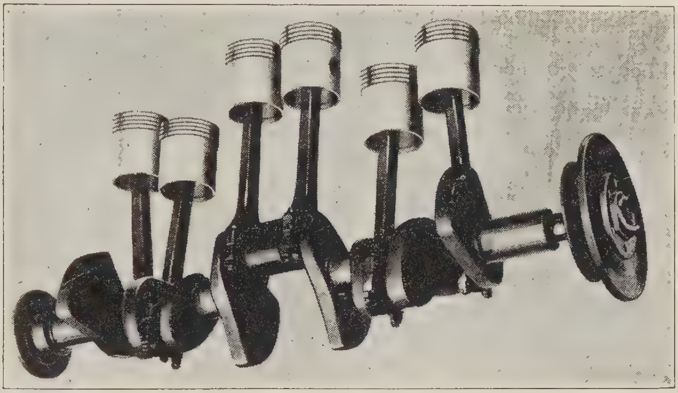


Fig. 5. Counterbalanced Crank Shaft

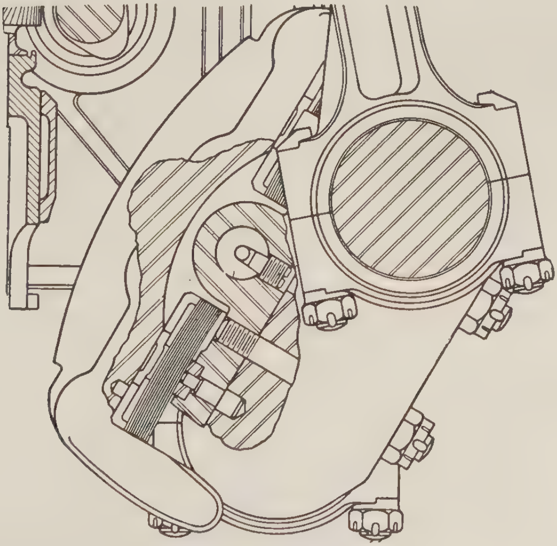


Fig. 6. Torsion Balancer Is Mounted on Crank Shaft between No. 1 and No. 2 Crank Pins

follows, therefore, that cams may be designed to give maximum power without the necessity for extreme quietness. Cam shafts are driven by both gear and chain, the latter type with automatic adjustment for taking up wear being shown in Fig. 8. Bearings should have sufficient clearance to avoid burning out under load. When taking up bearings, the usual practice is to allow .002-inch clearance for the oil film. Connecting rods must be in perfect alignment to avoid uneven wear on pistons and eliminate noise. Both cast iron and aluminum alloy are used for piston material. In some instances LO-EX pistons are used, which have the quality of extreme toughness with a low coefficient of expansion. This makes for long life, as they can be fitted more closely.

Fig. 7. Harmonic Balancer for Use on Forward End of Crank Shaft

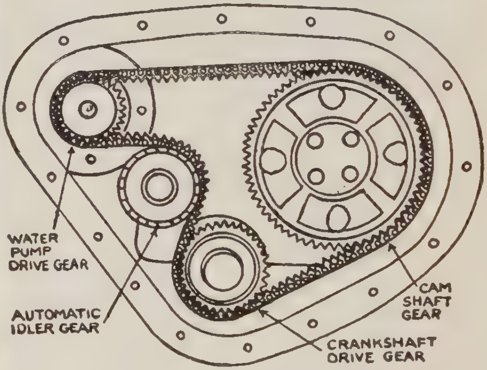


Fig. 8. Silent Chain Front-End Drive with Automatic Take-Up

In the fitting of piston rings, side clearance between the ring and ring land should be from .001 to .0015 inch and should not be allowed to exceed .0035 inch. End clearance should be .010 to .015 inch for a 4-inch cylinder and should not be allowed to exceed .025 inch. To avoid excessive wear of the rings in their grooves, care should be taken to see that the cylinder walls are straight and true. In the fitting of both pistons and rings, the manufacturer's recommendations should be strictly adhered to. Out-of-round and tapered cylinders are especially expensive, not only from the standpoint of loss of power but in the excessive amount of fuel and oil consumed.

In order to make the cost of renewal of the cylinders as reasonable as possible, many manufacturers have adopted the plan of making the cylinder walls removable. Fig. 9 shows in detail the method of holding the cylinder in place and how they may be removed. Gaskets at both top and bottom prevent water from entering the combustion chamber or crank case. By renewing cylinder barrels, pistons, and rings, a truck may be made to have as much compression and power as when new.

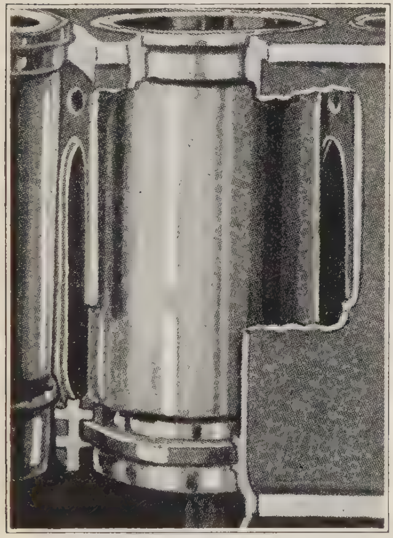


Fig. 9. Renewable Cylinder

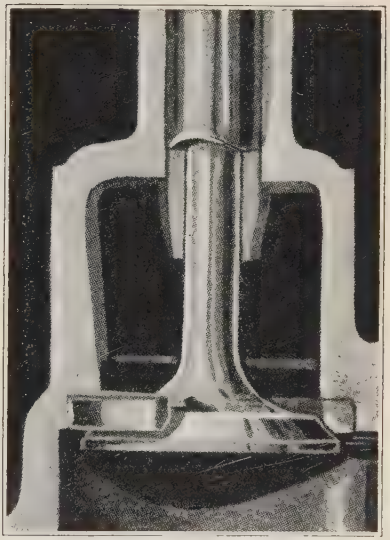


Fig. 10. Valve Insert

Valves. Because of the hard pulling a truck engine is often called upon to do, it is of extreme importance to have good valves. Manufacturers, therefore, use only the best of steel in making the valves and in order to prolong the life of the cylinder block, valve inserts, Fig. 10, are placed in the cylinder block. In Fig. 11 is shown the process of grinding in the valves with a pneumatic tool. To lessen wear due to the hammering action of the valve, both valve and seat are sometimes coated with a layer of stellite—a very hard metal, which greatly resists wear and eliminates the need for frequent valve grinding. When grinding is necessary, stones must be used for both re-seating and re-facing operations, Fig. 12, as reamers will not cut these hardened surfaces. After re-conditioning with stones, a slight touching up with a valve-grinding compound is usually advisable to insure a good job.

Valve Springs. The effect of proper valve spring tension on correct motor performance is frequently ignored or overlooked. Manufacturers have gone to a great deal of expense in determining the correct tension to place on the valve of their motor. Weak springs cause erratic operation at high speeds, while excessive spring tension consumes excessive power and causes rapid wear of valve and seat. When springs appear weak, they should be either tested on a reliable valve spring tester or their strength checked with that of a new spring. Valve spring dampers, Fig. 13, are often provided to

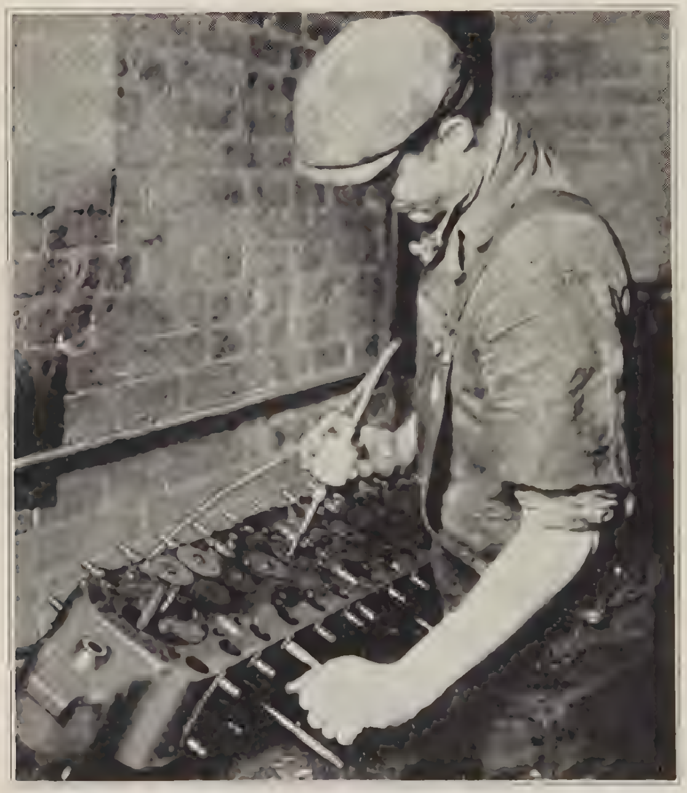


Fig. 11. Grinding in Truck Engine Valves with Pneumatic Tool

prevent valve spring "surge." These should be checked occasionally to see that they are functioning properly. Results of their application are shown in Fig. 14.

Valve Clearance or Lash. Excessive valve clearance is usually thought of as merely causing unnecessary noise. However, in truck engines it is important from the standpoint of power and economy and should be accurately maintained at all times. Care should be taken to see that the valve lifters are at the lowest point before the valves are adjusted, as it is very easy to assume that this condition exists when it does not because of the larger clearance recommended on truck engines. There are several methods of setting an engine so no error will be made, two of these—the "companion throw" and the "timer-distributor" are described in the order given.

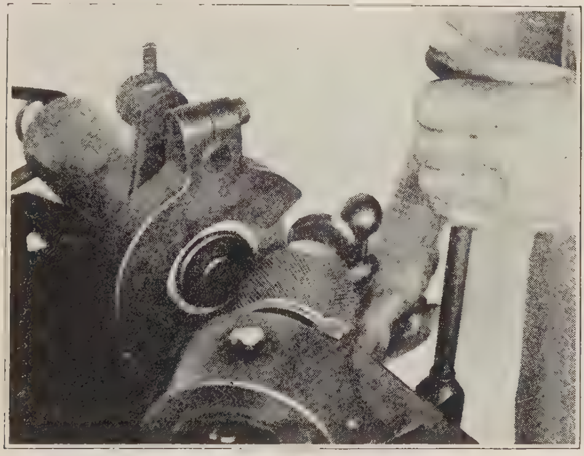


Fig. 12. Re-facing Valves (Note flat burned spot on valve face.)

On all conventional engines, the crank shafts are so made that two pistons move together. On a six-cylinder engine, companion throws are 1 and 6; 2 and 5; and 3 and 4. The pistons attached to these throws do not move out on power at the same time but, according to the four-stroke cycle principle, one cylinder fires on one revolution and its companion fires on the second revolution of the cycle. It is obvious that when the first piston goes out on power, the second will be going out on the intake stroke. Therefore if the engine is turned until the intake valve lifter on cylinder No. 6 is just getting tight, piston No. 1 will be close to top dead center on the compression stroke. Both valves will therefore be closed and may be adjusted. When the intake valve lifter is just getting tight on cylinder No. 5, adjust tappets on cylinder No. 2, and vice versa; and when intake valve tappet on cylinder No. 4 is just getting tight, adjust both valves on cylinder No. 3, and vice versa.

Use the timer-distributor method only when the distributor cap is plainly marked with spark-plug wire numbers, and it is known that the spark plugs are connected correctly according to these numbers. It is then only necessary to locate the terminal connected to spark plug wire No. 1. Remove distributor cap and turn engine until rotor is at this terminal, then adjust both valves on cylinder No. 1. Turn motor until rotor points to terminal connected to spark-plug wire No. 2, and adjust valve clearance on cylinder No. 2; then crank engine until rotor points to terminal No. 3, adjust valves on cylinder No. 3, and so on. After finishing, re-check work to be sure no errors have been made, as a variation in valve clearance will affect the valve

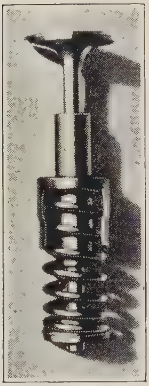


Fig. 13. Valve Spring Vibration Damper

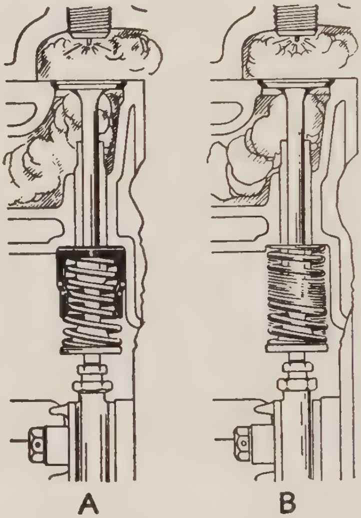


Fig. 14. At *A*, No Surge Is Shown Due to Valve Spring Damper; While at *B*, Erratic Action Is Shown of Valve Spring without Damper

timing. On valve-in-head engines, valve clearance may be adjusted with engine running.

Valve Timing. Both gears and chain are used for driving the cam shaft. When timing valves on the gear type, it is usually only necessary to match the timing marks on the crank-shaft gear, Fig. 15. In the case of chain drive, a string may be stretched, or a straightedge laid across the center lines of the crank shaft and cam shaft, and the marks on the crank-shaft and cam-shaft sprockets made to coincide with the string or straightedge. Allowance must be made for the slant of the teeth in gear drive or slack in chain if used, during the assembling operation. Before the timing cover is replaced, the job should be checked with flywheel markings or by position of the piston to make sure that no error has been made.

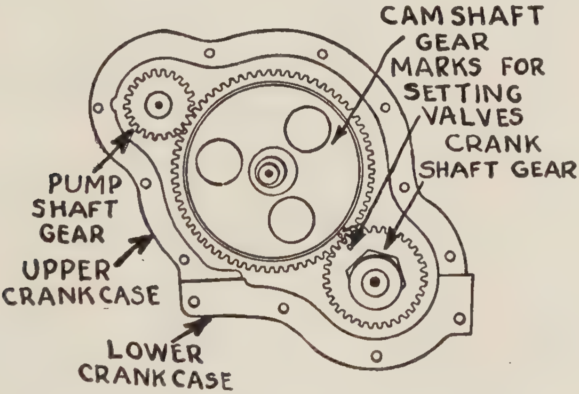


Fig. 15. Timing Marks

LUBRICATION SYSTEM

Realizing the importance of proper lubrication and knowing the strenuous duty to which the truck motor will be subjected, manufacturers have almost universally adopted the full-pressure type oiling system, Fig. 16. Oil is forced through the drilled crank shaft to main bearings, thence to connecting-rod and cam-shaft bearings. From connecting-rod bearings, it is forced through drilled connecting rods to the piston pins, the surplus being forced out to the cylinder walls, and then returned to the oil pan through oil control rings. Oil filters,

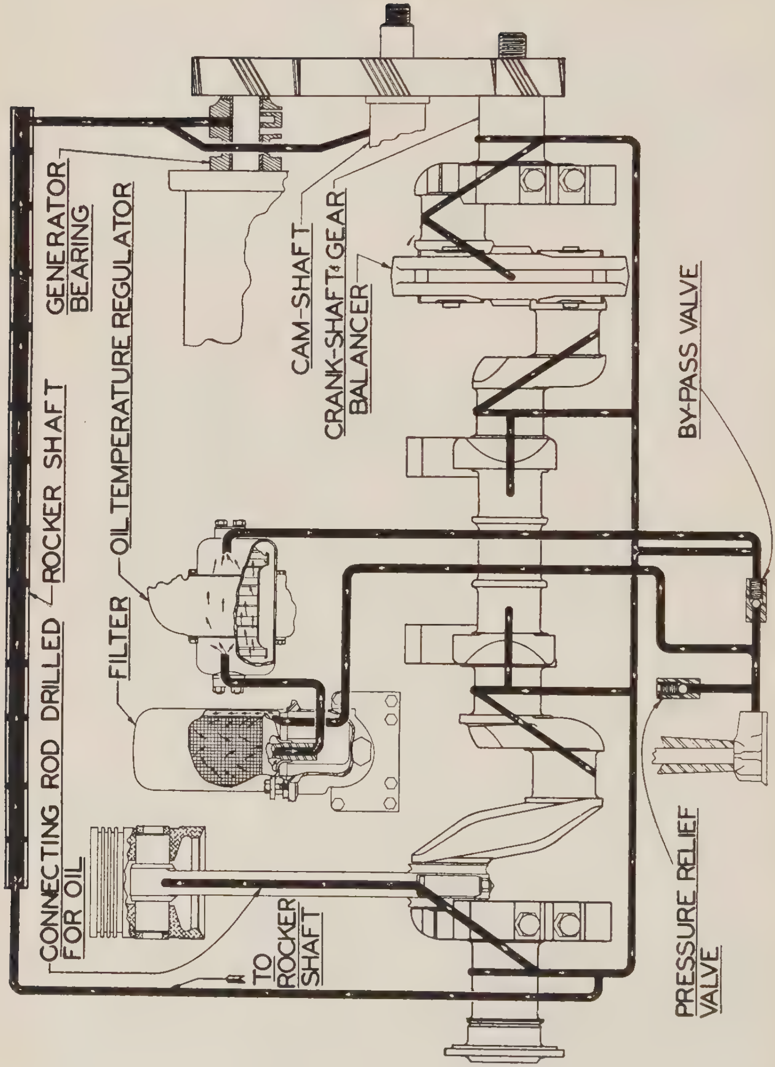


Fig. 16. Pressure Oiling System

Fig. 20, remove all harmful substance from the oil, while a fine screen in the oil pan or surrounding the pump prevents foreign material from entering the oil lines.

Manufacturer's recommendations should be followed with respect to the grade of oil to be used, and oil should be drained and replaced at regular intervals as it becomes diluted from blow-by and from the condensation of moisture within the crank case. Sulfurous acid is also a product of combustion and cases have been known where as much as one per cent has been found in the crank case of a truck engine where the nature of the work necessitated its operation for long periods of time at idling speeds. This is sufficient to cause corrosion and pitting of bright wearing surfaces, such as bearing journals, piston pins, and valve lifters. Remove oil pan periodically and clean thoroughly to prevent accumulation of sludge.

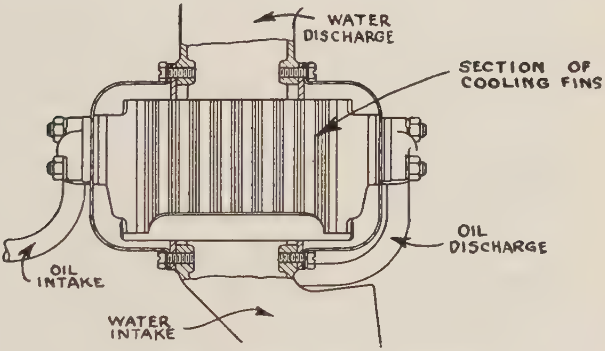


Fig. 17. Oil Temperature Regulator

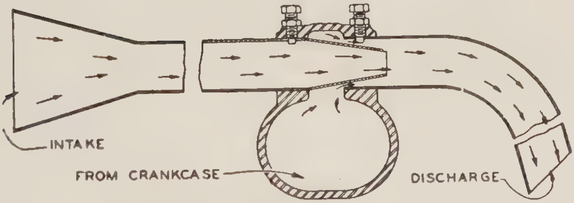


Fig. 18. Ejector Type Crank-case Ventilator Draws Gas and Water Vapors from Crank Case

Oil temperature regulators, Fig. 17, are sometimes used to maintain uniform oil temperature in both winter and summer, while crank-case ventilators, Fig. 18, rid the crank case of fumes and moisture. Being simple in construction, they require little servicing.

COOLING SYSTEM

No new principles are involved in the cooling of a truck motor. Forced circulation of the water is considered essential due to the severe conditions encountered. Radiators, cooling fans, and pumps are designed with a capacity great enough to satisfactorily cool the motor under the most unfavorable conditions. Fig. 19 shows a cross section of a water circulation pump with method of packing and lubricating. Only the best packing is used so as to avoid scoring and rapid wear of the shaft, the packing gland being kept only sufficiently tight to prevent leaks. Strands of rope or wrapping cord are unsatisfactory for packing material, for they are usually too harsh, thus causing excessive wear on the shaft.

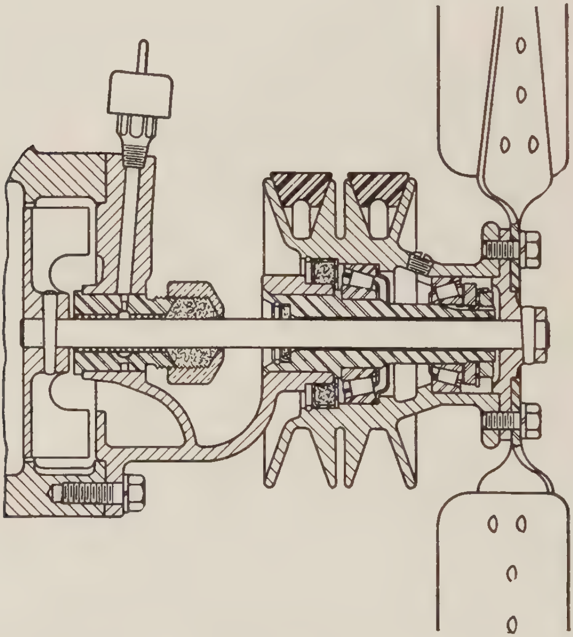


Fig. 19. Fan and Water Pump Assembly Shown Here in Section Is Mounted on Front of Cylinder Block

When lubricating the water pump, use only greases made specifically for such purposes. Avoid over lubrication, as the excess lubricant is forced into the cooling system where it attacks the radiator hose and may tend to clog the small radiator passages.

Fan belts must be kept at the proper tension. Fig. 21 shows one method of properly testing the adjustment. Another method is to increase tension of belt until the fan blades can be rotated by hand with difficulty. Excessive belt tension not only shortens the life of the belt, but it also causes high bearing pressure which may result in overheating. Fan blades should run true and be kept at the proper pitch.

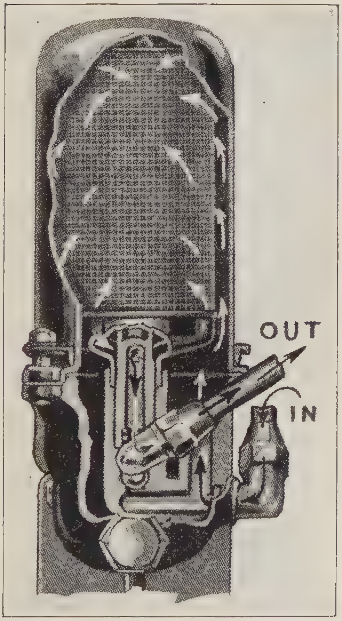


Fig. 20. Sectional View of Oil Filter

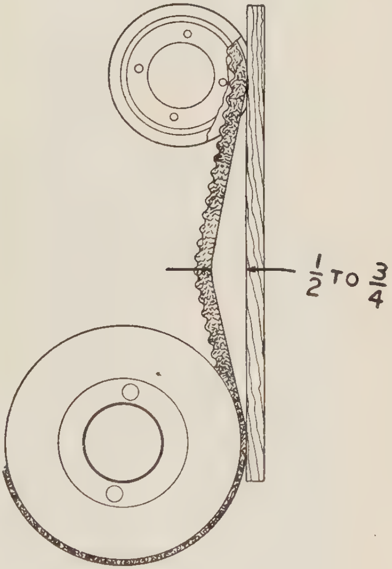


Fig. 21. Only Light Pressure Should Be Required to Deflect Fan Belt as Shown Above

Thermostats. Due to the fact that the cooling system on the truck motor is designed to provide adequate cooling under the most adverse conditions, it is necessary to provide some sort of device to maintain a uniform temperature under conditions when loads are light. This is accomplished by use of a thermostat, Fig. 22, which is usually placed in the upper hose connection close to the engine block, and consists of a butterfly valve actuated by a bellows filled with a special fluid which is very sensitive to changes in temperature. It has been found that an engine operates most efficiently at temperatures from 170 to 190 degrees Fahrenheit. The thermostatic valve is therefore adjusted so that it begins to open at approximately 140 degrees and is fully open at 155 to 160 degrees. Ordinarily the thermostat requires no attention; but if trouble should arise resulting in overheating of the motor, no attempt should be made to repair it, but a new thermostat should be installed and the old one discarded or returned to the factory for inspection and possible repair.

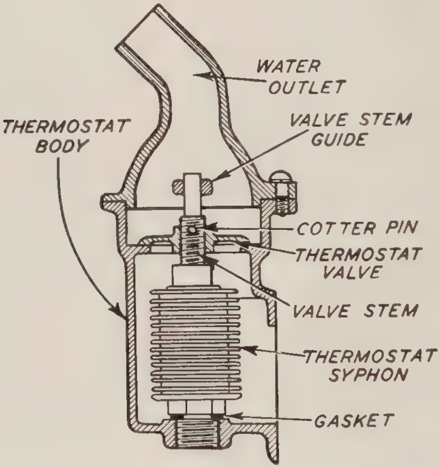


Fig. 22.
Thermostat Water Control

Carburetor. The construction and working parts of a Stromberg truck type carburetor are shown in Fig. 29. It is of the balanced type with fixed adjustments and an accelerating pump and economizer controlled by the vacuum of the engine. The idling mixture is drawn up through an idling tube and discharged through a small jet just above the throttle valve slightly above the idling adjusting screw which controls the amount of air introduced with the fuel at low speeds. A double venturi is used to maintain the suction at the tip of the main discharge jet at low speeds, thus providing proper mixture at all times. The accelerating pump is controlled by the vacuum of the engine. When the throttle is closed, suction draws the pump and by-pass plunger up against the tension of its spring, section *DD*, causing the pump chamber to be filled with fuel. As the throttle is opened, the vacuum decreases and the spring forces the plunger

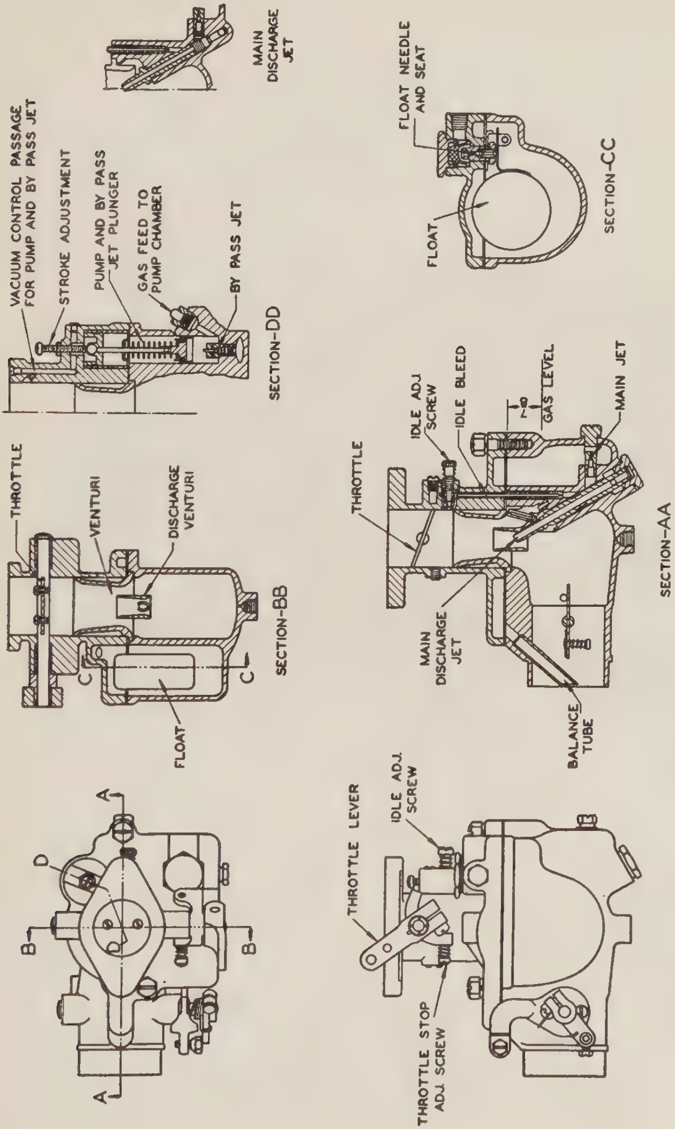


Fig. 29. Sectional View of SF Series Stromberg Carburetor

down, spraying the gasoline into the air stream and enriching the mixture for quick acceleration. Only one mixture adjustment is provided which is made at idling speed, as mentioned above. Turning the idling screw clockwise makes the mixture richer, while turning it counterclockwise makes it leaner.

To insure proper fuel vaporization throughout the complete range of atmospheric temperatures, a heat control is provided, having both winter and summer adjustments. For light pulling and city driving, the adjustment should be set in the winter position; while for continuous high-speed driving, it should be in the summer position.

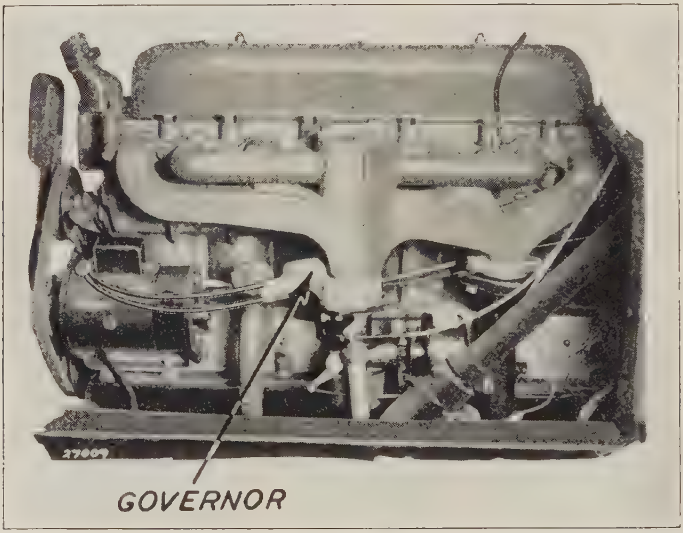


Fig. 30. Electro-Vac Speed Governor

Governors. Trucks designed for long continuous operation, as on express or freight lines, are sometimes provided with a governor, Fig. 30, to control the engine speed and prevent excessive depreciation of both truck and motor. Because of its simplicity, the air velocity type is the most common type used at the present time. It consists of a butterfly valve mounted a little off center on a shaft and held open by a spring, the tension of which can be varied. As the engine speed increases, the velocity of the air becomes great enough to close the valve against the tension of the spring, thus preventing speeds above a predetermined figure. As the load increases and the engine slows down, the velocity of the intake air diminishes and the spring opens the valve, supplying a larger charge to take care of the increased demand.

AIR CLEANERS

Commercial trucks are sometimes operated under most unfavorable conditions. Dust and particles of abrasive often fill the air and, if drawn into an engine, cannot fail to shorten the useful life of the engine. The importance of air cleaners cannot well be overemphasized The oil type, Fig. 31, is considered one of the very best for truck use. It operates as follows: Air entering the center tube passes down into the oil chamber. Due to its velocity and to the sudden reversal of direction of flow, most of the dust is thrown into the oil and settles to the bottom. The partially cleaned air then masses upward through a dense mass of oil-wetted copper mesh where all remaining dust is caught, thus allowing only clean air to enter the carburetor.

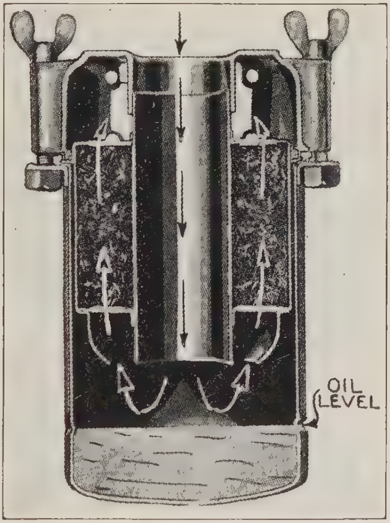


Fig. 31. Sectional View of Triplex Air Cleaner

The cleaner requires no attention other than an occasional cleaning. To do this, remove the oil reservoir and copper-mesh cleaner element. Wash off accumulated dirt from element by plunging it up and down several times in a can of gasoline or kerosene. Blow out with compressed air and then dip in heavy engine oil, allowing excess to drain off while cleaning and re-filling reservoir. The latter should be thoroughly cleaned with gasoline and re-filled to the proper level with heavy engine oil. Unless cleaned periodically, as conditions require, air cleaners will not function properly and may, in some instances, aggravate the condition which they are designed to prevent. For example, if the cleaner is allowed to become clogged with dirt, it will restrict the flow of air to the carburetor, causing increased fuel consumption by producing an effect similar to driving with a partially closed choke. This will result in overheating, excessive crank-case dilution, and loss of power. If cleaner is left in a dirty condition until the dirt dries and cakes on the wire mesh, large pieces will break away and be drawn into the engine, causing unnecessary wear. The air cleaner should be cleaned at least every 1000 miles. Under exceptionally dusty or dirty conditions, it may be necessary to service it much oftener than this; perhaps every 100 or 200 miles, or at the end of each day's driving.

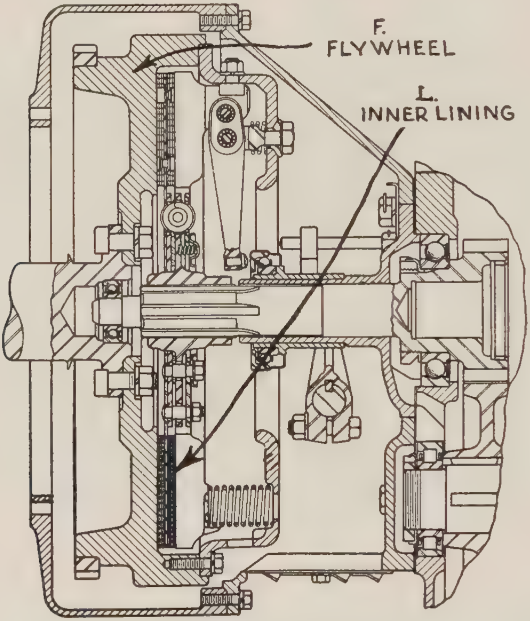


Fig. 32. Single Dry Plate Type Clutch

TRUCK CLUTCHES

Plate Type Clutch. From the standpoint of construction, no new principles are involved in the design of truck clutches with the possible exception of more rugged makeup. Because of its smoothness of operation, uniform wear, and ease of operation, the plate type is the most commonly used, Fig. 32. The flywheel *F* forms the front half of the clutch housing and is faced off smooth to provide a friction surface for the inner lining *L*. The clutch plate (or clutch disc), slidably connected to the clutch shaft through splines, is located between and riveted to the clutch linings, and the whole assembly is held firmly against the flywheel by eighteen springs, each having a pressure of approximately 110 pounds. These bear equally against the pressure plate. Six release levers, with hardened buttons on the end, bear against the annular ball throw-out bearing. A clutch plate of the cushion type is shown in Fig. 33. Ten large compression springs absorb shocks due to sudden engagement and act as a damper to smooth out torsional impulses and vibration. Where unusually heavy hauling is encountered, the air-operated triple plate clutch, Fig. 34, is used. The V-block method of providing engagement gives tremendous force with light pedal pressure.

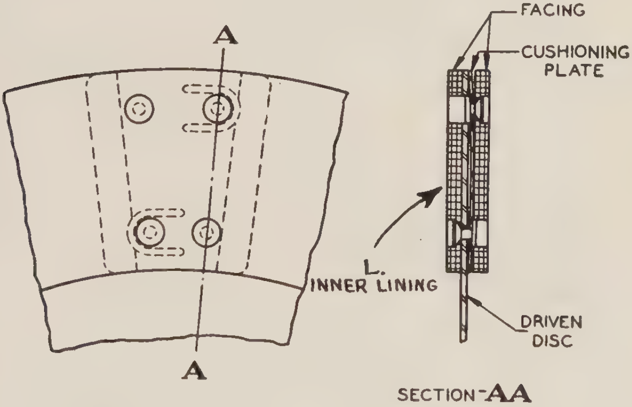


Fig. 33. Attach Lining to Tongue Portion of Cushion Plate

Care and Adjustment. Few modern plate type clutches have provision for adjustment. As wear occurs, the clutch springs merely force the pressure plate closer to the flywheel, automatically taking up wear. During this time, however, the clutch pedal is brought closer to the floor board. Hence, it is important to maintain proper clutch pedal-toe-board clearance. To prevent an unequal engage-

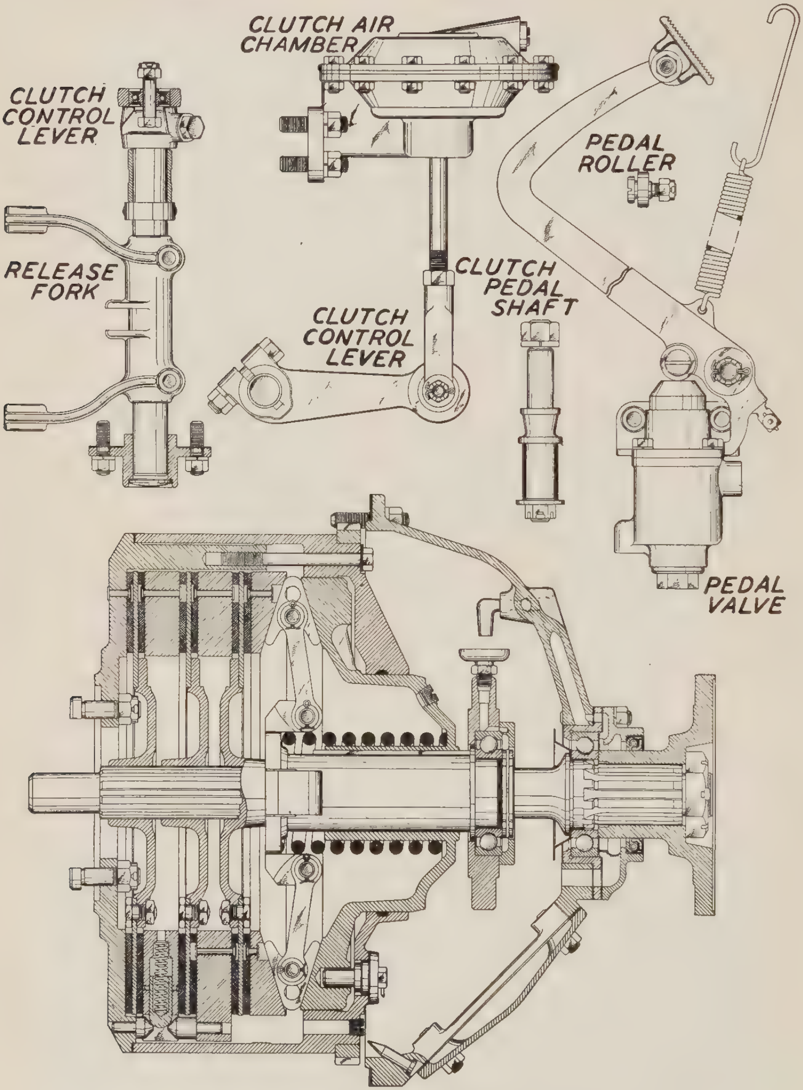


Fig. 34. Air-Operated Triple-Plate Clutch
Courtesy of The White Company, Cleveland, Ohio

ment, the clutch release levers must all have exactly the same clearance between their hardened ends and the clutch release bearing. Inspection of this should be made if the clutch shows a tendency to grab. Oil which has become rather hard and sticky from the heat of the friction will also cause rough operation. In such cases, flush out thoroughly with kerosene by closing the drain hole in the bottom of the housing and pouring in about one quart of kerosene. Run the engine at idling speed, depressing the clutch pedal several times to permit the kerosene to reach all parts of the clutch. Drain thoroughly before using.

A slipping clutch may be due to oil on the linings or to weak spring tension. In the event it is oil on the linings, flush out thoroughly. If this does not effect a remedy, the springs should be removed and their tension compared with that of a new spring. The clutch throw-out bearing should receive periodic lubrication, but care should be taken not to overdo the job as the excess lubricant will find its way into the clutch facings and cause trouble. The practice of "riding" the clutch should be avoided in order to prolong the life of both linings and throw-out bearing. Also the practice of allowing the clutch to slip excessively when starting, to attain greater acceleration, is to be condemned. Use a lower gear ratio and permit the clutch to engage with as little slipping as possible.

TRANSMISSIONS

Modern trucking requirements demand that trucks be adaptable to both high-speed and heavy-duty work. Manufacturers have accordingly taken full advantage of the quietness afforded by constant-mesh helical gears in designing their transmissions, and have made transmissions with at least five forward speeds, three of which are "quiet."

Overdrive and Underdrive. In general, truck transmissions may be classified under two heads, namely, the overdrive and the underdrive. In the former, direct drive is in fourth speed; while in the latter, direct drive is in fifth. It is obvious, therefore, that the overdrive would be utilized where high speed was essential, and the underdrive where pulling power was the main requirement. A typical five-speed truck transmission is shown in Fig. 35. It will be noted that anti-friction bearings are used throughout to prolong life and

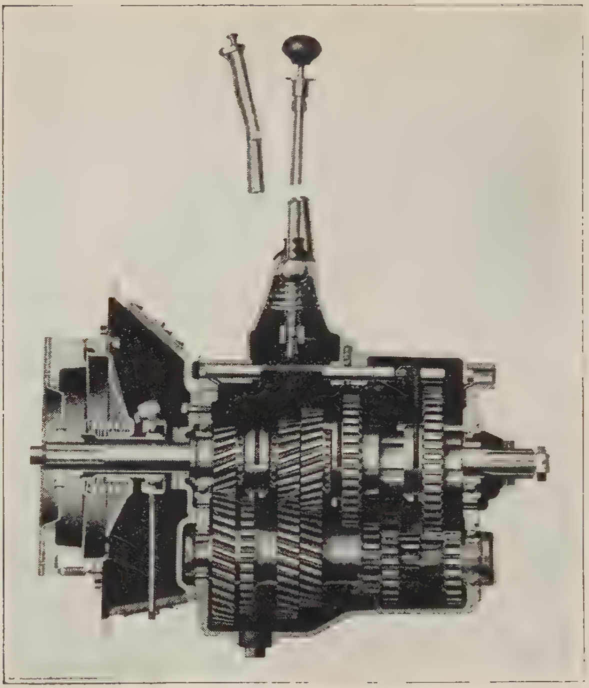


Fig. 35. Brown-Lipe Five-Speed Gear Set

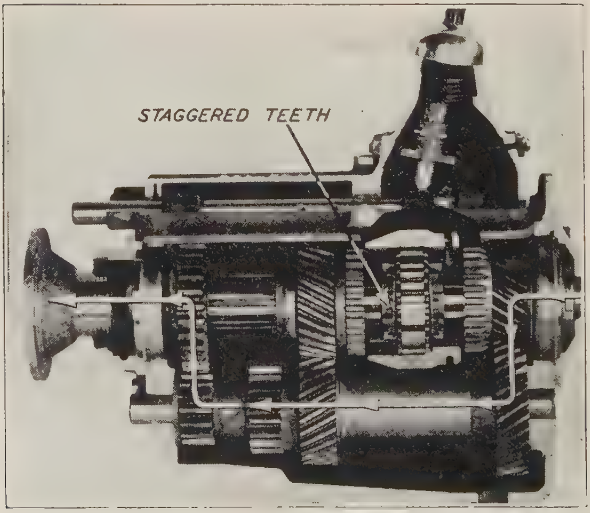


Fig. 36. Staggered Teeth "A" on Shifting Dog

keep maintenance cost at a low figure. With constant-mesh gears, shifting is no more difficult than in the automobile. Not satisfied with the constant-mesh feature alone, some makers stagger the teeth as shown in Fig. 36. The result is a quieter and easier shift with less likelihood of grating the gears. Figs. 37 and 38 illustrate, respectively, gear-shift lever positions on typical five-speed overdrive and underdrive transmissions.

Power Take-Off. Due to the prevalence of the demand for power lifts and self-dump features, most transmissions have provisions on one or both sides where connections may be made for operating such conveniences by using the power of the engine. Where hauls are of considerable distance, the saving of the time required for unloading becomes of great importance. Especially is this true in road construction work where trucks may be operated in large fleets. Fig. 39 shows a power-lift self-dump truck in operation on the Boulder Dam project.

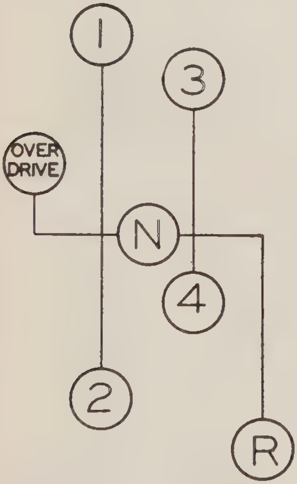


Fig. 37. Gear-Shift Lever Positions for Five-Speed Unit-Mounted Transmission

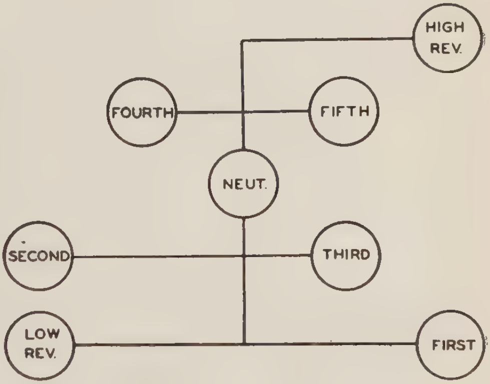


Fig. 38. Gear-Shift Lever Positions for Underdrive Transmission

Care of Transmissions. Truck transmissions should be drained every ten or twelve thousand miles, and the case flushed thoroughly. Worn or loose parts should be replaced and fresh oil added, the level being checked each 1000 miles thereafter.

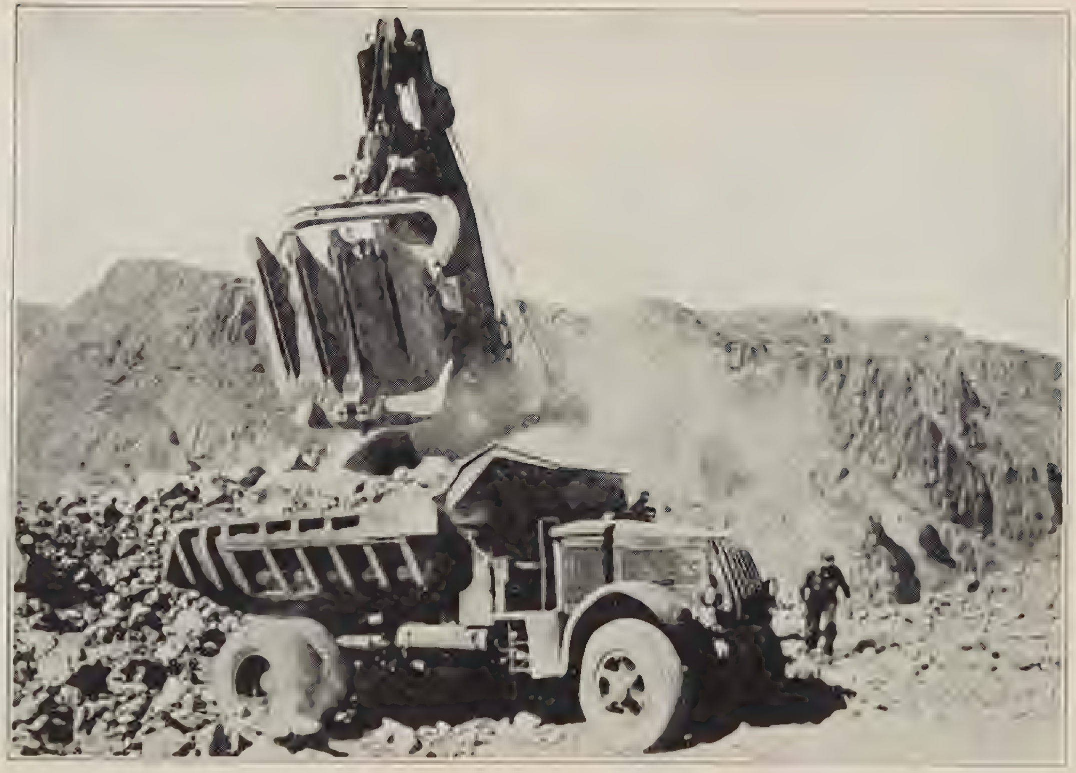


Fig. 39. Power-Lift Self-Dump Truck in Operation on Boulder Dam Project

REAR AXLES

Full-Floating Rear Axle. With the exception of trucks of small capacity, manufacturers are pretty well agreed on the full-floating rear axle as the most satisfactory and trouble-free type for truck use. This design, Fig. 40, necessitates having two bearings on the outer end of the axle housing, which increases the cost of manufacture but makes for greater strength and reliability. Axle shafts extend through the housing, being secured to the wheel hub by means of a flange and cap screws. The axle shaft, therefore, does not function in any load-carrying capacity, but has only to turn the wheel and perhaps take a certain amount of side thrust. This construction also simplifies the replacement of shafts, should one break in service, as it is not necessary to dismantle the entire axle or disturb the wheels to install a new shaft. Housings are usually of the banjo type, which permits inspection or adjustment of the gears by simply removing the rear cover plate. The differential corresponds to standard rear-axle construction.

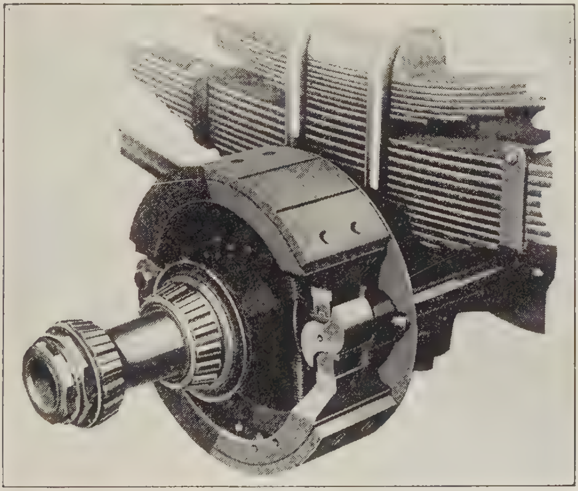


Fig. 40. Six-Ton Federal Truck Full-Floating Axle with Westinghouse Brakes

Ring Gear and Pinion Drive. The capacity of the truck usually dictates the method of final drive employed. The spiral bevel ring gear and pinion, which has been most universally adopted in the automobile field, is popular where conditions are not too severe and capacities too great. Because of the principle on which bevel gears operate, they must be held rigidly in alignment in order to give satisfactory service and long life. The transmission of heavy torque causes the gear to attempt to back away from the pinion, and vice versa. Bearings must therefore be of generous capacity; and the ring gear and differential housing must be of ample strength to resist this thrust. To increase the rigidity of the pinion, the straddle type of mounting is used. A "back-up plate" mounted directly back of the ring gear maintains proper alignment by supporting the ring gear when it tends to back away from the pinion under unusually heavy loads.

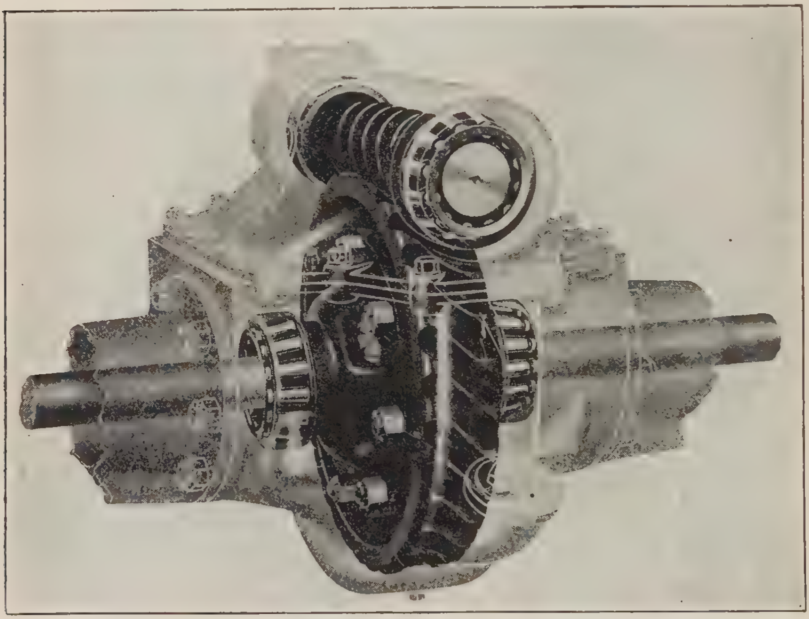


Fig. 41. Worm and Gear for Rear Axle, Showing Upper Position of Worm

Worm Drive. Where conditions are exceptionally severe, the worm drive, Fig. 41, has proved to be very satisfactory. As thrust loads are very high, lubrication must be positive and complete in order to avoid the possibility of cutting, with the attendant loss of power and upkeep expense.

Double Reduction Gear Drive. Another type of rear-axle drive designed for heavy duty consists of a combination of the spiral bevel and spur gear types, Fig. 42. Because of the double reduction feature, Fig. 43, thrust loads are lessened on the bevel gear and pinion, and the use of silent herringbone gears eliminates the presence of thrust in the final drive. This drive is popular for heavy trucking because of its ability to withstand punishment without continual servicing.

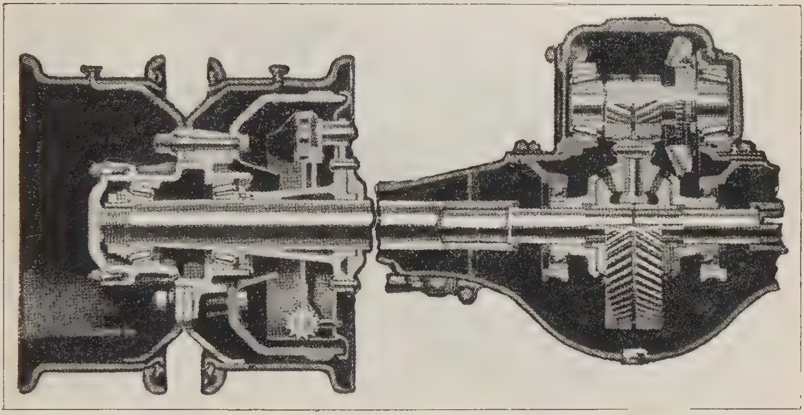


Fig. 42. Herringbone Rear-Axle Gear

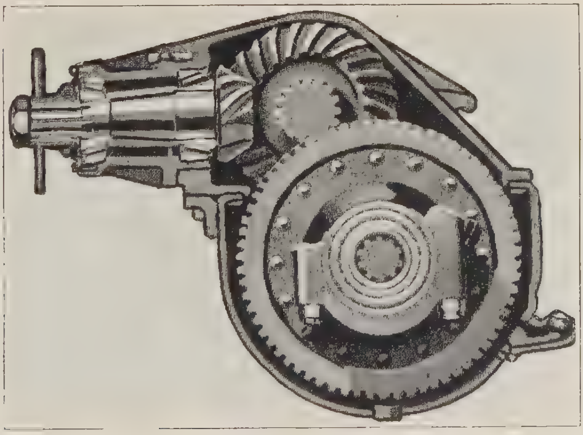


Fig. 43. A Double Reduction Drive

Two-Speed Rear Axle. Rather than complicate the transmission with a large number of speeds, a two-speed rear axle may be used as illustrated in Fig. 44. Using the standard three-speed transmission and the low ratio of the two-speed rear axle, a great amount of torque is available for heavy pulling. By shifting to the high rear-axle ratio, higher road speeds are possible without an increase in engine speed. Thus there are six speeds forward and two reverse, which is a slight increase over the standard type of five speeds. In most cases, a variety of transmission and rear-axle ratios are available, and the purchaser may choose those most nearly fulfilling his requirements.

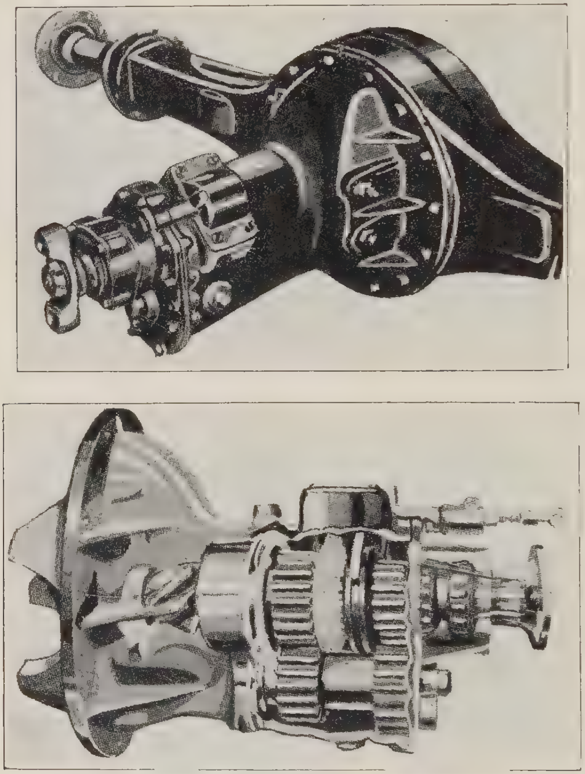
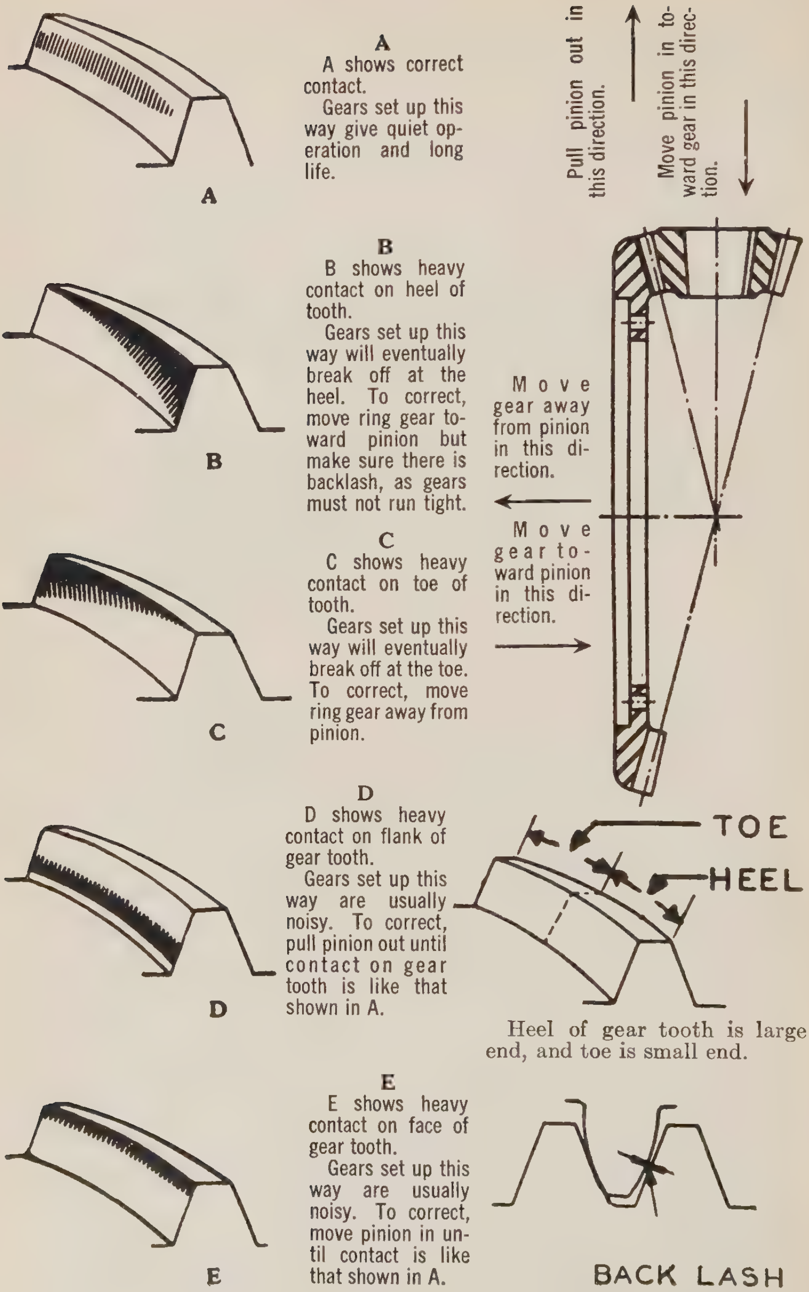


Fig. 44. Two Views of Two-Speed Rear Axle

Service and Care. If properly lubricated and adjusted, rear axles give little trouble unless subjected to abuse or overloading. A generous overload capacity is built into every truck, because of the well-known tendency of owners to overload. The final drive assembly should receive periodic inspection, and adjustments made when necessary. Bearings must not bind, neither should an appreciable amount of play be evident. Differential carriers may be moved sidewise by tightening up on the bearing on one side of the differential carrier and loosening the opposite one a like amount. These adjustments must be made carefully and accurately. Care should be taken when adjusting ring gear and pinion to maintain proper backlash. The chart, Fig. 45, shows the method of securing proper bevel gear tooth contact and adjustment. Proper tooth contact may be determined by cleaning ring gear and pinion thoroughly, painting a number of teeth with red lead, and then operating for a few moments in both forward and backward directions. Correct contact will be shown by results similar to that shown at *A*. In case the contact is similar to that shown in illustrations *B*, *C*, *D*, or *E*, correct by making the adjustments indicated. Where the double reduction type of drive with herringbone gears is used, it will be noted that both assemblies must be moved together to avoid poor adjustment in one or the other.

In the worm drive, care should be taken when adjusting differential bearings to maintain proper alignment between worm wheel and worm shaft. When re-adjusting for wear, original alignment can usually be secured by taking up all extra clearance with the adjusting ring on the right side. To re-adjust bearings, take off lock plate and tighten adjusting ring on right side until all end clearance is taken up. Then back off one notch to secure proper end clearance of .004 to .006 inch, and install lock plate. When installing differential in carrier, it is necessary to adjust differential bearing to provide proper contact between worm thread and wheel teeth. Fig. 46 shows correct contact when looking at rear end of carrier. Drive face of wheel tooth is toward you and is shown by the shaded area. Coast contact area is on the opposite side of tooth and is shown with dotted line. Note that the worm threads enter wheel teeth at the left side and leave at the right side. Therefore, with power applied, the worm tends to push wheel toward the right side. By adjusting wheel slightly off center toward the left side, contact area is shifted to center of teeth when full power is applied. It is not necessary to check coast contact as it is always relative to drive contact. Before attempting to adjust for alignment, make sure that worm shaft bearings are in correct adjustment. Then adjust differential bearings until worm wheel is approximately on center with worm shaft. Paint drive face



A

A shows correct contact.

Gears set up this way give quiet operation and long life.

B

B shows heavy contact on heel of tooth.

Gears set up this way will eventually break off at the heel. To correct, move ring gear toward pinion but make sure there is backlash, as gears must not run tight.

C

C shows heavy contact on toe of tooth.

Gears set up this way will eventually break off at the toe. To correct, move ring gear away from pinion.

D

D shows heavy contact on flank of gear tooth.

Gears set up this way are usually noisy. To correct, pull pinion out until contact on gear tooth is like that shown in A.

E

E shows heavy contact on face of gear tooth.

Gears set up this way are usually noisy. To correct, move pinion in until contact is like that shown in A.

Pull pinion out in this direction.

Move pinion in toward gear in this direction.

Move gear away from pinion in this direction.

Move gear toward pinion in this direction.

Heel of gear tooth is large end, and toe is small end.

Fig. 45. Chart Showing Method of Securing Proper Bevel Gear Tooth Contact

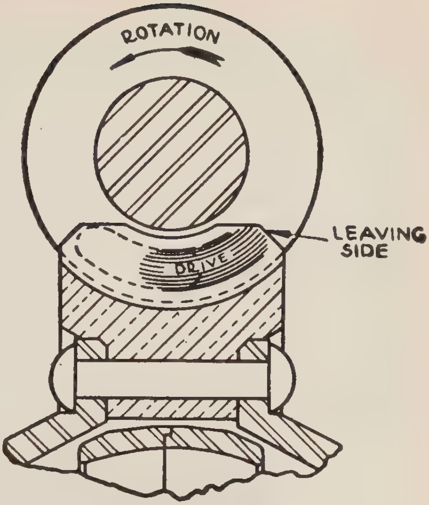


Fig. 46. Worm and Wheel Contact Chart

of teeth with a very thin coat of Prussian blue. Rotate worm shaft clockwise, looking from the front (as when driving truck forward) at the same time holding slack out of wheel. Worm will wipe the blue from the teeth, thus showing contact area. Correct contact should be obtained by shifting differential one or two notches off center toward the left side. Radius rods, if used, should have an end clearance of approximately .010 inch. Freedom from binding is very necessary when making this adjustment.

BRAKES

With the development of improved roads, the problem of proper brakes has become more and more important. In the old days with dirt roads, solid rubber tires, and rather small trucks capable of running at an average speed of about 20 miles per hour, the necessity for powerful and efficient brakes was not so important. With brakes on only the rear wheels and in fair condition, a driver who used ordinary precaution could operate a truck safely. However, with the development of interstate express and freight hauling, where many tons are hauled overland at speeds of 45 to 50 miles per hour, it is essential that proper methods of braking be installed to provide safety for truck and cargo, and for other users of the highway.

Present design would warrant classifying truck brakes under three general headings, namely, strictly driver-controlled (manual effort) mechanical brakes, vacuum booster brakes, and air brakes.

Mechanical Brakes. The mechanical brake is used on the smaller trucks where the force required for operating does not exceed the strength of the average man. Adjustment, maintenance, and service operations are, for the most part, similar to those of an automobile. Consequently, the information and service advice set forth in the automobile brake section apply as well to the mechanical type as used on trucks. It is essential that all cables and levers operate freely with no binding, and that all joints be kept properly lubricated in order that the entire force exerted by the operator will be utilized in applying pressure to the drums. Freely working joints will also insure maximum economy from the engine, as no power will be lost through dragging brakes.

Power Brakes. This type of braking system is similar to the mechanical brake with the exception of a power cylinder which is connected to the brake pull rod, the piston of which is actuated by atmospheric pressure or, as more commonly known, the vacuum in the intake manifold. It is a well-known fact that the atmosphere exerts a pressure of 14.7 pounds per square inch at sea level. By proper choice of cylinder size, it is possible to obtain a total force of several hundred pounds for use in the application of power brakes.

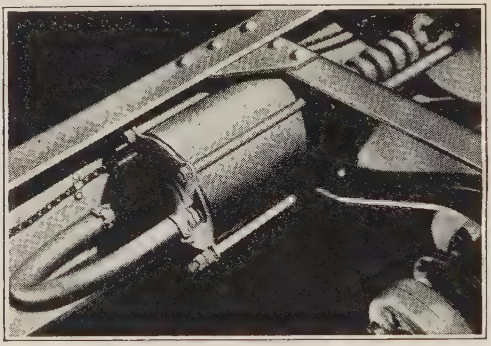


Fig. 51. Booster Brake on Three-Ton Studebaker Truck

The power unit consists of one or more cylinders, Fig. 51, made of drawn steel tubing with end plates of die castings fitted with a heavy-duty leather piston-rod seal. A felt ring is inserted in the end plate to clean and provide lubrication for the piston rod. The piston is made of steel plate fitted with a suitable leather packing ring. A flexible guide protects the portion outside the cylinder from dirt and grit. The operation of the power cylinder is as follows: When the brake pedal is in the "off" position, vacuum from the intake manifold is present on both sides of the piston, causing it to be "suspended" in a vacuum, hence the name vacuum suspended type.

When the brake pedal is depressed, the operating valve cuts off the vacuum on one side and admits air at atmospheric pressure, causing the piston to move toward the end in which vacuum still exists. Power thus developed is transmitted to brake linkage through a pull rod, and results in the application of the brake. When the brake pedal is released, the operating valve cuts off the atmospheric pressure and admits engine vacuum with the result that there is balanced pressure on both sides of the piston, and retracting springs release the brakes.

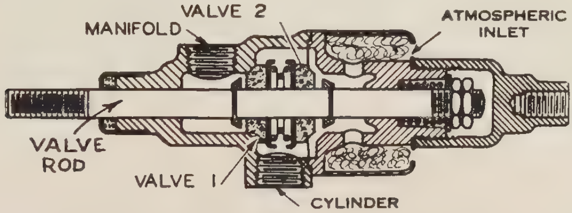


Fig. 52. Brake Operating Valve in "Applied" Position with Valve No. 1 Closed, and Valve No. 2 Open
One side of cylinder is now open to atmospheric pressure.

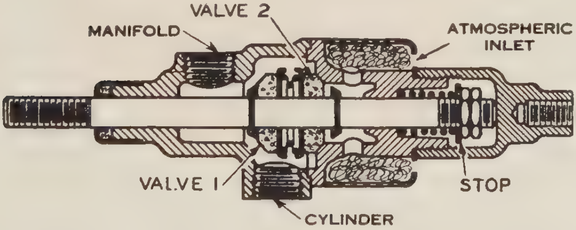


Fig. 53. Brake Operating Valve in "Off" Position with Valve No. 1 Open
Both sides of cylinder are now open to intake manifold.

A clearer conception of the operation may be obtained from Figs. 52 and 53, which show the brake operating valve with brakes in the "applied" and "off" positions. When pedal is depressed, the valve rod is moved forward (to the left), Fig. 52, opening valve No. 2 and closing valve No. 1. Air at atmospheric pressure is then admitted through air cleaner by way of the inlet to the atmospheric side of piston. This forces the piston toward the vacuum side of the cylinder, applying the brakes. When the foot pedal is released, the valve rod is moved to the right, Fig. 53, closing valve No. 2 and shutting off atmospheric pressure in the cylinder. Valve No. 1 then opens so that both sides of cylinder are again connected to intake manifold. Pressure on both sides of piston is thus equalized and brakes are released by retracting springs. A typical arrangement of a vacuum booster brake layout is shown in Fig. 54. Brake shoe operation, adjustment, and maintenance are similar to those of the mechanical type.

In addition to an operating valve, a check valve is an important part of the vacuum-controlled brake. Its purpose is to maintain maximum vacuum in the entire system in order that fluctuations will not occur with varying throttle positions. It also insures at least one booster brake application in case the engine should stall. In trailer installations it is also a valuable addition, as it assures an automatic application of the brakes in case the trailer becomes accidentally detached from the truck.

SERVICE INFORMATION

Instructions presented apply to booster equipment only. For information on mechanical adjustment of brakes, shoes, and linkage, consult reference for the particular type used.

Air Cleaner. The cleaner should be examined and cleaned at least twice a year. After removing cover, wash filter material thoroughly in gasoline, then saturate with medium engine oil before re-installing.

Lubrication. Power cylinder piston should be lubricated at least every 3000 miles with a good grade of cylinder oil having a low pour test. The cylinder piston rod guide should be lubricated every 6000 miles. If a reservoir is provided, it should be filled at the above mentioned intervals. Oil should not be poured in the air inlet, as it tends to obstruct the free passage of air and rots the rubber over the piston rod guide. External valves do not require lubrication, but should be disassembled at least twice a year and thoroughly cleaned of all corrosion.

Testing Brakes. A preliminary test to determine whether trouble exists in the power brake assembly may be made in the following manner.

1. Stop engine.
2. Depress brake pedal about one inch.
3. Start engine, taking care not to move pedal.

If power unit is working, the pedal will go down of its own accord, and the brake trouble lies in some other part of the system. If there is no change in the pedal position after engine starts, trouble exists in the booster equipment. The length of the rod between the foot pedal and valve should never be changed, as this will greatly affect the correct working of the power cylinder. This is set on each individual installation at the factory and need never be changed. In case of an emergency when brakes fail to release and the cause cannot be quickly determined, disconnect the nipple on the vacuum line at the intake manifold and insert a plug. This will render the power cylinder inoperative, and the brakes may be operated manually by the driver until a service station can be reached. If, after disconnecting the vacuum line, the brakes do not release, the trouble lies in the braking system itself and not in the power equipment.

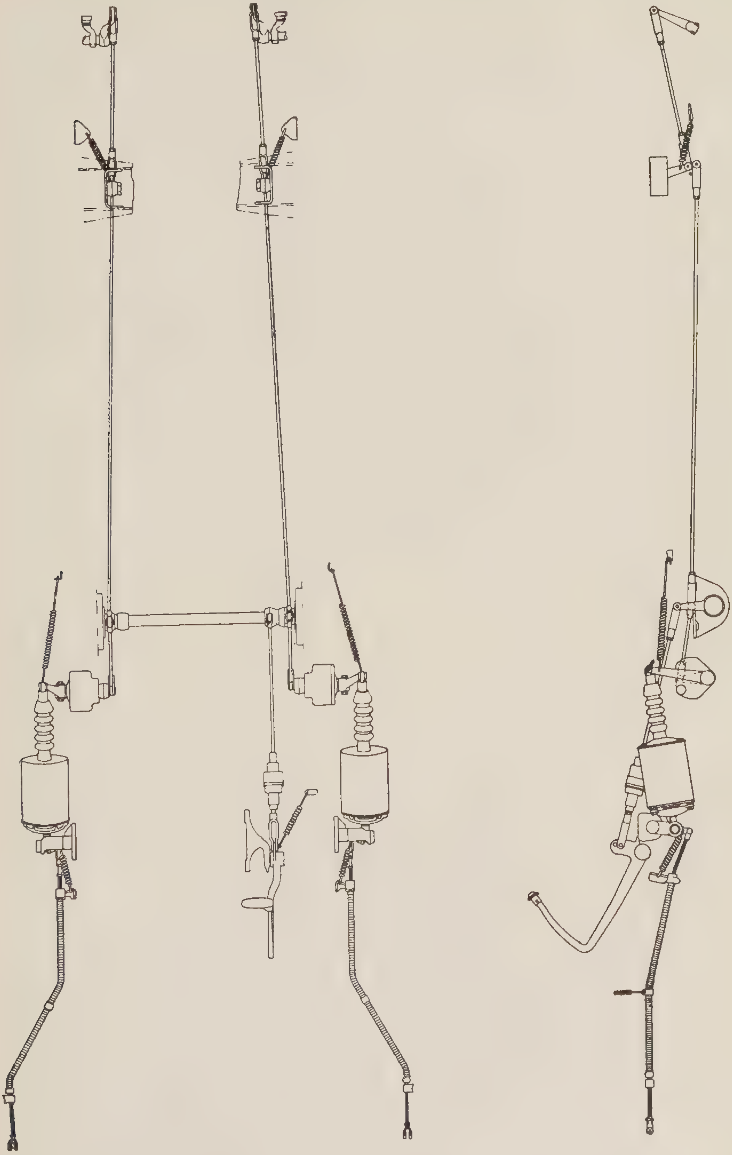


Fig. 54. General Arrangement of Brake Control Layout

Testing the Vacuum. If the vacuum appears to be low a check-up may be made as follows: Remove the pipe plug on the end plate of cylinder, and install a vacuum gauge. With engine running, vacuum should reach 17 to 20 inches of mercury. Shut off engine, and note whether vacuum falls off rapidly, or is retained for a reasonable length of time. If the former condition exists it indicates a leak which should be located and remedied.

Air Brakes. Where great braking power, safety, ease of control, and reliability are desirable characteristics of a system, no method has proven superior to the Westinghouse air brake. One great advantage lies in the ease and practicability with which it may be applied to units over long distances. It works equally as well on long trains of a hundred cars or more, as it does on a single locomotive. Due to the demand for greater speeds and the prevalence of trucks and tractor-trailer combinations, it is gaining prominence in this field and bids fair to outdistance all others in popularity and efficiency. Fig. 55 shows a truck air brake layout as used in General Motors Model T-758 truck. Brake shoes are of the two-shoe internal expanding type, hinged at one end and expanded at the opposite end by specially designed cams which exert constant pressure on the shoes regardless of angular position.

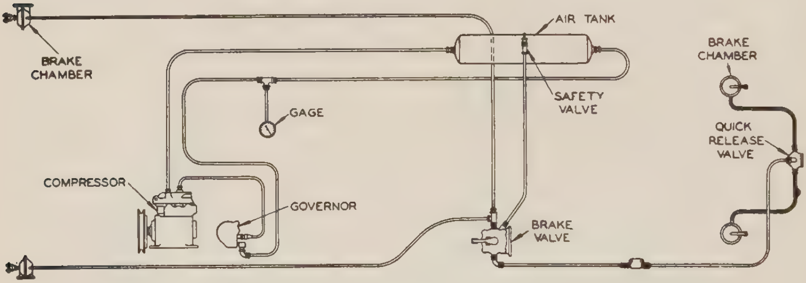


Fig. 55. Brake Layout Showing Position of Units

A vertical two-cylinder single-acting air compressor, Fig. 56, is mounted on the side of the engine and driven by a belt in conjunction with the fan. It is of the open-base type and has a capacity of six cubic feet. Both water and lubrication systems are connected to the corresponding unit of the engine. At high speeds, the compressor operates against a head of 100 to 105 pounds air pressure. Discharge valves are of disc type spring loaded, and located in cylinder head. Unloading valves are also located in the cylinder head and are adjusted to remain closed until tank pressure reaches 105 pounds.

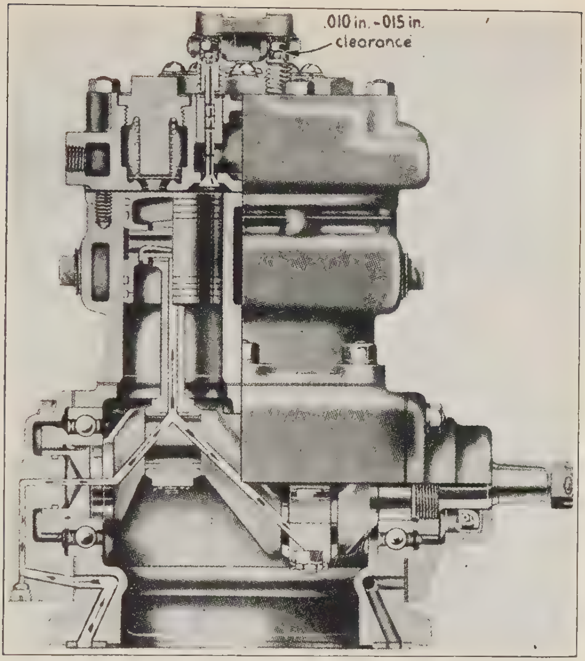


Fig. 56. Sectional View of Air Compressor

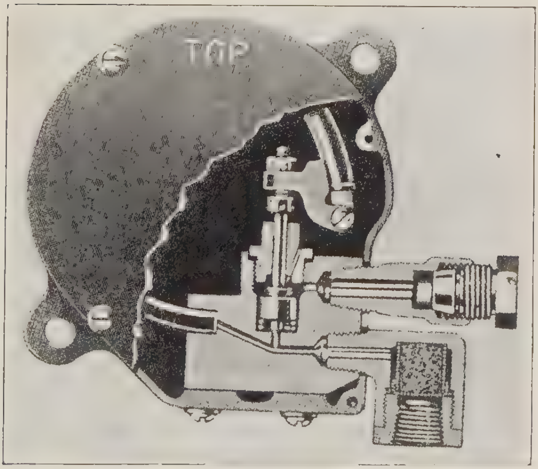


Fig. 57. Air Pressure Governor Is Mounted on Side of Compressor

A pressure governor, Fig. 57, regulates the pressure between maximum and minimum settings of 105 and 90 pounds, respectively.

The compressor operates continuously while engine is running, but governor functions to cut out compressor at 105 pounds, thereafter allowing compressor to operate without any compression. The governor closes valve when pressure drops to 90 pounds. The brake application valve, Fig. 58, operated by foot pressure, controls brake operations by directing the flow of air from reservoir to brake chambers when brakes are applied, and from brake chambers to atmosphere when brakes are released. The amount of air admitted is proportional to pedal pressure, the brake chamber pressure being controlled to a fine degree between minimum and maximum by movement of brake pedal, thus making it possible to gradually set or release the brake as conditions demand. Air brake chambers, Fig. 59, are located at each wheel with pull rods for operating the actuating cam of the brake shoe. The air line is connected to one side of the chamber, and a push plate attached to the brake rod assembly. A quick release valve, Fig. 60, is mounted between the front brakes to speed up release of front wheel brakes.

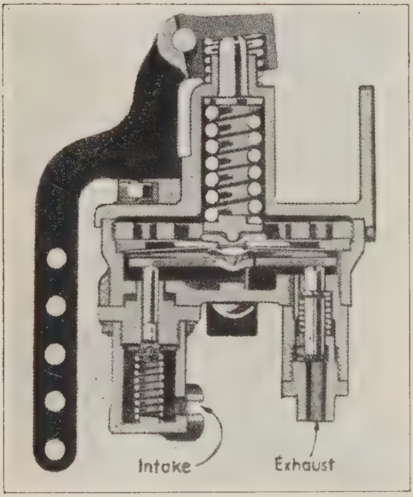


Fig. 58. Sectional View of Brake Application Valve

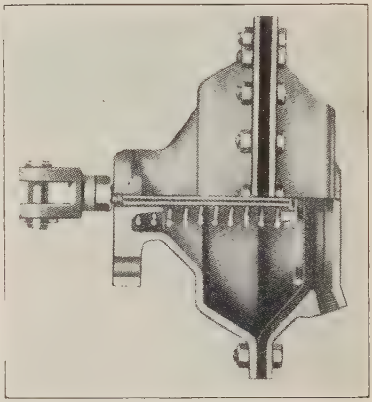


Fig. 59. Sectional View of Brake Chamber

The cylinder head of the compressor should be removed every 5000 miles and carbon removed from pistons, valves, valve seats, springs, and air passages. Exhaust and unloading valves should be reseated at this time, using soap. Do not use grinding compound. Connecting-rod bearings should be inspected for wear, and adjusted if necessary to .002-inch radial clearance. If compressor fails to build up pressure, examine for broken line or connections. Lack of pressure is quite often due to a stuck exhaust valve. Replace or clean valve and spring. Unloading valve adjusting screws should have .010 to .015-inch clearance, while drive belt is adjusted to have approximately ¾-inch deflection. The horsehair filter in governor inlet fitting should be removed and cleaned every 5000 miles. Open drain cock daily in air storage tank to drain off accumulated water due to condensation. Damaged air tanks should be replaced and no attempt made to repair them. Before starting on a run, the pressure gauge on dash should read between 60 and 105 pounds. If low, brakes will not function properly. In case of serious trouble in any unit, it is well to proceed slowly to the nearest service station before a serious accident occurs.

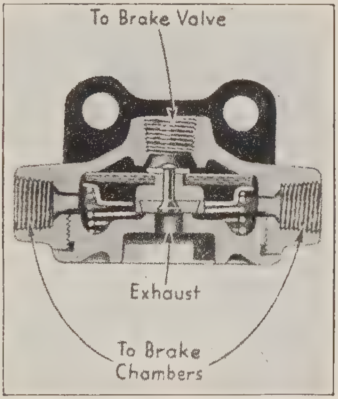


Fig. 60. Quick Release Valve

SELECTING A TRUCK

Prospective purchasers of trucks are interested in knowing the advantages to be gained in changing their method of hauling, and the profits to be gained by making such a change. At the present stage of development of the truck industry, the question of what make to buy is of minor importance, as manufacturers have improved their product to the point where with proper care and attention as to loading, any standard make will give satisfactory service.

Hauling Conditions Vary Greatly. There are three important questions from the standpoint of the truck's ability to do the work expected of it, which the buyer of a truck will want answered. First, the capacity of the truck—how much it will haul. Here, of course, the size of the body and cab, location of engine, size and strength of chassis, etc., all enter into the picture. Distribution of load has a direct bearing upon the handling of the truck especially in ascending and descending hills. Naturally, the operating conditions may increase or decrease the capacity of a truck under various circumstances. For instance, a two-ton truck might have ample capacity and power to haul 2 tons over hard roads under average conditions. But the same truck might have a capacity of only 1 ton when pulling stone or gravel out of a deep pit where the ground is loose or soft.

The second question is, does the truck have sufficient reserve power to haul its full-rated load over the average highway in direct drive. It is not intended here to convey the idea that all trucks should be powered with a motor capable of climbing all hills in high gear with a full load. However, it is true that less power is lost in direct drive than when transmitted through gears. It follows, therefore, that the greatest efficiency and satisfaction will occur if the load can be hauled as much as possible in direct drive. Oversize trucks, on the other hand, are not necessarily the solution of the problem. Cases have been known where owners were induced to buy an oversize truck to avoid overloading, with the result that operating expenses were so prohibitive that a change was made within a short time to a truck which, when loaded, weighed less than the previous truck empty. The result was not only increased economy of operation, but greater ease of handling, and no appreciable expense due to possible overloading.

Operators who are inclined to overload might, of course, make such a change with negative results. However, trouble more often arises from overloading a small truck than from purchasing one too large for the job. In fact, a manufacturer recently stated that the average truck buyer's interest lay in the truck's overload capacity, rather than in mechanical details; that buyers, to save on first cost, choose the smallest truck possible with the deliberate intention of overloading. This is hardly the proper attitude to assume if one wishes to achieve economical results.

The third point which should be considered in the selection of a truck is the operating speed, and whether this is best suited for the work the truck is to do. This involves the proper relation between size of engine and transmission gear ratios. A truck geared low for heavy pulling will rattle itself to pieces when forced to keep up with traffic, while one geared primarily for high speed will be sluggish or inefficient, due to the necessity for too frequent gear shifting. It is important, then, for the prospective purchaser of a truck to consider all angles of a situation before making a final decision.

Miscellaneous Features. In some cases unusual conditions demand special features not ordinarily found in conventional truck construction. Transcontinental and interstate express trucks often operate on a night-and-day schedule. Where two drivers divide the time behind the wheel, a sleeper cab, Fig. 61, is provided which enables one operator to obtain proper rest while off duty. Although more or less of an innovation, the sleeper cab has met with immediate acceptance. The berth is located under the seat, and when not in use has the appearance of a standard cab. It has the necessary width to permit a normal adult to rest comfortably on the spring mattress provided. This is reached by removing the right cushion, which is placed on end in an upright position and securely held in place on the right front edge of the seat riser, thus forming a half partition between the cowl and berth, breaking drafts and subduing normal noises. The berth is 24¾ inches wide by 73 inches long and may be entered without disturbing the driver. This is an example of special conveniences which may be had in order that certain definite time schedules and routes may be organized with the assurance that uniform service can be maintained over long distances.

Manufacturers are at present doing everything in their power to help the buyer achieve satisfactory truck performance. Complete and detailed information is at hand at all times indicating what any particular truck is capable of doing with the various transmission ratios available. "Ability ratings" are sometimes utilized for quickly determining the proper transmission and rear axle ratios to provide power to meet the road conditions encountered. This is a very convenient method of determining the capacity of a truck. For example, if a truck with standard gear ratio has an ability rating of 8500-4½-51, it would mean that it is capable of hauling a gross load of 8500 pounds over a grade of 4½ per cent in direct drive, and that its operating speed on level hard bottom roads is 51 miles per hour. If the truck buyer has quite a few 5 per cent grades and does not wish to do too much gear shifting, an ability rating of 8500-5-45 may be had by changing size of tires and gear ratios. It will be noted here that 6 miles per hour top speed has been sacrificed for hill-climbing ability.

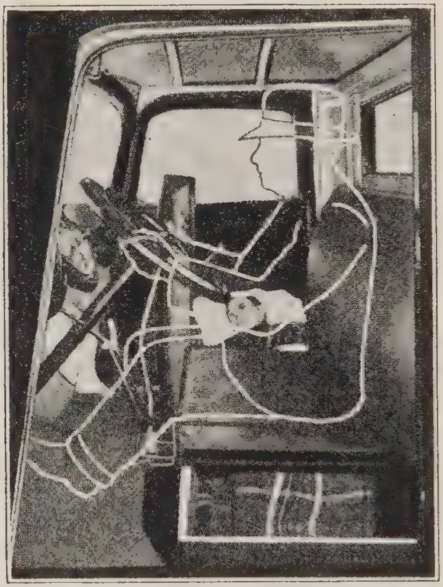


Fig. 61. Trucks Should Fit the Driver

The prospective truck buyer will do well to analyze his trucking problems carefully, determining maximum load to be carried, distance to be hauled, and speed required for schedule maintenance. With this information at hand, he may then approach his local dealer whose experience along with data furnished by the manufacturer should establish the size best adapted to the work to be done.

INDEX

The page numbers of this volume will be found at the bottom of the pages; the numbers at the top refer only to the section.

See Complete General Index, Vol. VI

Page

A

Air bag 188
Air binding 350
Air brakes 442
Air brakes—operation and service 212
  commercial uses 215
  compressed 213
  pressure system 212
  vacuum system 214
Air cleaners 423
American Society for Testing Materials 373
Aniline number 371
Artillery-type pressed-steel wheel 140
Atlas-Imperial fuel-injection system 363
Automobile wheels, balancing 145
Axle straightening 57

B

Bag-type filter 380
Balloon tires, inspecting, repairing, and vulcanizing 174
Barrel type master cylinder 267
Bearing clearance 394
Bendix
  brake-drum lathe 232
  duo-servo brakes 278
  duo-servo hydraulic brakes 301
  power brake units 239

Page

Bendix-Westinghouse automotive air brake equipment 243
B.K. vacuum power brakes 237
  Bendix power brake units 239
  Studebaker power brake unit operation (all models) 237
Bleed-off line 349
Boiling-point-gravity number 373
Bosch
  injection pumps 352
  plunger 355
  pump timing 356
  spray valve 350
Box type master cylinder 272
Brake adjustments 263
Brake bands or drums 219, 250
Brake-drum lathes 232
  Bendix 232
  South Bend 234
  turning the drum 235
  uses 236
Brake drums—friction 209
Brake drums—reconditioning 231
Brake leverage 218
Brake relining 227
Brake rods 287
Brake service 216
  adjusting brakes 219
  brake leverage 218
  equalizers and rods 219
  hydraulic system 218
  mechanical systems 218

Note.—For page numbers, see foot of pages.

Page

Brake service (continued)
  motor vehicle brake performance 221
  new equipment and methods 216
  out-of-round brake bands or drums 219
  trouble shooting chart 220
Brake shoe design 210
Brake-testing and brake-testing equipment 221
Brakes 203–310
  air brakes—operation and service 212
  Bendix duo-servo brakes 278
  B.K. vacuum power brakes 237
  brake-drum lathes 232
  brake relining 227
  brake service 216
  brake-testing and brake-testing equipment 221
  braking systems 203
  Buick 306
  Chevrolet huck type brakes—servicing 288
  Chevrolet hydraulic brakes 249
  compressed air brakes 213
  Ford 'V-8" brakes 291
  hand brake 254
  Lincoln-Zephyr 205
  Lockheed hydraulic brakes—servicing 255
  Midland steeldraulic T-section brakes—servicing 284
  reconditioning brake drums 231
  sealing against water 301
  standard model Chevrolet brakes—servicing 290
  transmission brakes 299
  truck 437
  vacuum operated trailer coach brakes 240
  Warner electric trailer brake 247
  wheel brake units 269
Braking systems 203
  brake drums—friction 209

Page

Braking systems (continued)
  brake shoe design 210
  commercial use of vacuum brakes 215
  compressed air brakes 213
  hydraulic brake system 206
  mechanical brake system 204
  servo action 208
  vacuum operated trailer coach brakes 240
  Warner electric trailer brake 247
Buick brakes 306
Buick chassis 17
Buick front wheel alignment 44
Bus wheels 141

C

Cadillac steering gear 64
Cam and lever steering gear 64, 80
Camber 31, 42, 51
Camel-back for retreading 190
Caster 30, 42, 50, 56
Caster angle 24
Cast-steel wheels 142
Center steering 72
Check valve 269
Chevrolet brakes (servicing) 290
Chevrolet huck type brakes—servicing 288
Chevrolet hydraulic brakes 249
Chevrolet knee-action front-wheel suspension 35
  care of 37
  double-action shock absorbers 35
  housing 35
  main soil spring 36
  needle or roller bearings 36
  operation 37
  radius rod or bracing arm 36
  removing spring unit 38
  replacing front spring unit 38
  secondary coil spring 36
  specifications 37
  spring adjustment 36
  wheel support arm 36

Note.—For page numbers, see foot of pages.

Page

Chevrolet and Pontiac front wheel suspension 24
Chevrolet truck and passenger car through-type front axle 49
Chrysler and Plymouth independently-sprung front wheels 28
Coil spring 36
Compressed air brakes 213
Cummins Diesel 383
- camshaft drive 384
- connecting rod 385
- crankshaft 385
- fuel injector 362, 387
- fuel oil 386
- fuel pump 386
- oiling system 386
- piston and piston pin 385
- valves 384
- vaporizer 389

Cuno Auto-Klean Filter 379

D

Diesel-fuel-oil classification 373
Diesels for transportation 311–338
- after chambers 322
- air injection 319
- common-rail 320
- compression pressures 324
- compression ratios 324
- direct injection 319
- distributor system 321
- double-acting Diesel engines 318
- flash point 325
- four-stroke cycle 315
- fuel charge 325
- fuel system 324
- fuels 325
- glow plugs 324
- Hercules "DHX" four-stroke Diesel cycle engine 327
- ignition point 325
- individual pump 320
- injection valves 322
- lubrication 326

Page

Diesels for transportation (continued)
- pre-combustion 319
- pressure relief valves 322
- single-acting Diesel engines 318
- solid injection 319
- spray nozzles 322
- starting systems 325
- two-stroke cycle 317

Drag link 67
Dual tires 163

E

Elliott front axle 45, 46
Essex spare wheel 137

F

Fairbanks, Morse high-speed Diesel 391
- connecting rod 394
- cooling water 396
- crankpin clearance 394
- cylinder heads 391
- cylinder liner 395
- frame 391
- fuel system 392
- governor 394
- injection timing 394
- lubricating system 396
- main bearings 394
- piston head clearance 395
- piston pin 395
- piston rings 395
- rocker clearance 392
- starting 396
- valve gear 392

Filters 379
Ford center-poise springing 104
Ford "V-8" brakes—operation, adjustment, and replacement 291
Ford "V-8" brakes 298
Front-axle hook-up (steering gear) 60

Note.—For page numbers, see foot of pages.

Page

- **Front axles** 45
  - Elliott type 45, 46
  - Hudson-Terraplane 45
  - I-beam 49
  - materials 48
  - repair operations 53
  - tubular axles 49
- **Front suspension—front axles—steering gears** 11–94
  - Cadillac 64
  - Chevrolet knee-action front-wheel suspension—servicing 35
  - Chevrolet truck and passenger car through-type front axle 49
  - front axles 45
  - independent springing of wheels 11
  - knee-action wheels 15
  - Packard 27
  - servicing Chrysler and Plymouth independently-sprung front wheels 28
  - steering gears 59
  - Studebaker independent front-wheel suspension 40
- Front wheel camber 42
- Front-wheel toe-in 42
- **Fuel for high-speed engines** 369
  - aniline number 371
  - boiling-point-gravity number 373
  - carbon residue 372
  - choice of fuel 374
  - combustion knock 369
  - filters 379
  - fuel handling system 376
  - ignitibility 370
  - supply tank 376
  - tests 370
  - transfer pump 377
  - viscosity 372
  - viscosity-gravity number 373
- **Fuel-injection systems** 339
  - Atlas-Imperial system 363
  - Bosch injection pumps 352
  - Bosch spray valve 350

Page

- **Fuel-injection systems (continued)**
  - common-rail systems 347
  - constant-stroke pumps 342
  - Cummins fuel system 359
  - Ex-Cell-O fuel pump 358
  - fuel control 341
  - fuel injector 367
  - fuel spray valves 347, 350
  - Hesselman nozzle 351
  - jerk-pump injection 340
  - timing fuel pumps 367
  - variable-stroke pumps 341
  - Westinghouse 352
- Fuel injector 367
- Fuel pump timing 367
- **Fuel pumps for high-speed Diesels**
  - Bosch 353
  - Cummins 359, 386
  - Ex-Cell-O 358
  - Fairbanks, Morse 392
  - timing 367
- Fuel spray valves 347
- Full-circle retreading machine 200
- Full-floating piston pin 395

G

- Gemmer steering gears 73
- Glow plugs 24
- Goodyear airwheel for automobile 153
- Goodyear criss-cross method of balloon tire repair 177

H

- Hand brake 254
- **Hercules "DHX" four-stroke Diesel cycle engine** 327
  - clearances, DHX series 333
  - constructional features 334
  - operation 327
  - specifications 331

*Note.—**For** page numbers, see foot of pages.*

Page

Hercules Diesel engine construction 334
  combustion chamber 337
  cylinder block 338
  cylinder head and valves 338
Hesselman nozzle 351
High-speed Diesel engines 311–404
  Cummins 383
  Fairbanks, Morse 391
  fuel for high-speed engines 369
  fuel-injection systems 339
  Winton 397
Hollow metal spoke wheels 136
Horsepower 309
Housing 35
Huck brake shoe design 212
Hudson-Terraplane brake control system 303
Hudson-Terraplane dual-hydraulic brakes 305
Hudson-Terraplane radial control front axle 45
Hydraulic brake piping 253
Hydraulic brake system 206
Hydraulic injection 340

I

I-beam front axle 49
Ignitibility 370
Ignition quality 374
Impulse injection 340
Independent springing of wheels 11
Injector cup 388
Injector plunger 388
Inner tube repairs 170
Integral tank type master cylinder 268

K

King-pin angle 32
King-pin inclination 51
Knee-action wheels 15
  Buick chassis 17
  caster angle 24

Page

Knee-action wheels (continued)
  Chevrolet and Pontiac front wheel suspension 24
  Packard front wheel suspension 27
  rolling on turns 18
  servicing new spring suspension 23
  shock absorbers 24
  special tires required 23
  spring carries load only 18
  spring wheel operation 17
  steering arrangement 19

L

Lockheed hydraulic brakes—servicing 255
Lockheed hydraulic four-wheel brake system 259
Lubrication (chassis) 29
Lubrication systems
  Cummins 386
  Fairbanks, Morse 392

M

Manufacturers' recommended specification data for high-speed Diesel engines 375
Marine fuel oil piping diagram 380
Master cylinders 271
  barrel type 267
  box type 272
  integral tank type 268
Mechanical brake system 204
Mechanical brakes 463
Midland steeldraulic T-section brakes—servicing 284
Motor vehicle brake performance 221

N

Nash balanced ride 98
Nash ball-bearing steering column 88
Nash Bendix duo-servo hydraulic brakes 302
Needle or roller bearings 36

Note.—For page numbers, see foot of pages.

Page

O

- Oilite spring inserts and bushings 107
- Oldsmobile front end suspension 44
- Orifice diameter 349

P

- Packard front wheel suspension 27
- **Passenger car wheels** 134
  - disk 140
  - pressed-steel disk 140
  - welded steel spoke 139
  - wire 136
  - wood 134
- Pitman arm stop 88
- Pitman shorter arm 89
- Pivot angle 32
- Pontiac horsepower chart of triple-sealed hydraulic brakes 309
- Port-controlled fuel pumps 345
- Power brakes 438
- Pressed-steel disk wheel 140
- Punctures and blowouts 170

R

- Radius rod 36
- Rain-proof cap for fuel supply tank 376
- Rear axles for trucks 431
- Rocker clearance 392
- Ross cam and lever steering gear 79
- Ross cam and twin lever steering gear 83

S

- Saginaw roller-bearing steering gear 85
- Scored needles 350
- **Shock absorbers** 24, 35, 119–132
  - Delco direct-acting 129
  - Delco-Lovejoy-Buick 123, 125
  - Delco-Lovejoy single-action 126
  - Delco shock absorber links 125
  - double-action 35
  - Ford Model "A" Houdaille hydraulic 121

Page

- **Shock absorbers (continued)**
  - Gabriel hydraulic 120
  - Oldsmobile knee-action 122
  - servicing the Ford hydraulic 122
  - sway bars and stabilizers 131
- South Bend brake-drum lathe 234
- Spill-valve control 344
- Spray nozzles 322
- Spray pressure 349
- **Spray valves** 347
  - Bosch 350
  - differential-needle type 348
  - Hesselman 351
- Spring adjustment 36
- Spring camber 43
- **Spring and shock absorbers**
  - Hudson-Terraplane ride control 107
  - Nash balanced ride 98
  - sway bars 131
- Spring suspension 23
- Spring wheel operation 17
- **Springs** 95–119
  - Chevrolet front wheel suspension unit 103
  - coil 101
  - Dodge 112
  - fabric spring covers 118
  - Ford center-poise springing 104
  - Ford spring shackles 114
  - Ford "V-8" 105
  - Hotchkiss drive 100
  - Hudson-Terraplane 107, 111
  - independent front wheel suspension 102
  - lubricating springs 116
  - metal spring covers 115
  - Nash balanced ride 98
  - oilite spring inserts 107
  - semi-elliptic 98
  - silent U-shackle 109
  - threaded type 113
- Standard model 1934 Chevrolet brakes—servicing 290
- Steeldraulic brake shoe design 211

Note.—For page numbers, see foot of pages.

Page

Steering
- angles 29
- arrangement 19
- gear kick shackle 70
- geometry 52

Steering gear troubles 89
- cross-rod connections 91
- ease of steering 94
- lost motion and backlash 89
- lost motion in wheel 90
- lubrication 92
- spring shackling and king pins 93
- tire inflation 92
- tires wearing out 91
- wheel wabble 91

Steering gears 59
- Cadillac 64
- cam and lever 64
- center steering 72
- drag link 67
- front-axle hook-up 60
- Gemmer 73
- Nash ball-bearing steering column 88
- Pitman arm stop 88
- Pitman shorter arm 89
- Ross cam and lever 79
- Saginaw roller-bearing 85
- steering-gear kick shackle 70
- tie rod 69
- troubles 89
- worm and gear steering gear 61
- worm and nut gear 63
- worm and roller type gear 65, 87
- worm and three-tooth sector steering gear 66

Stop lamp switch 253
Studebaker independent front-wheel suspension 40
Studebaker hill holder 307
Studebaker power brake unit 237
Suction throttling 342
Suction valve control 343
Sway bars and stabilizers 131

Page

T

Tables
- Diesel-fuel-oil classification 373
- ignition quality 374
- manufacturers' recommended specification data for high-speed Diesel engines 375

Thermostats 419
Timing fuel pumps 367
Tie rod 69
Tire loads 155
Tire mounting and dismounting 167

Tires 147–202
- cables 151
- camel-back for retreading 190
- care 157
- dimension and weight data 156
- drop-center rim tire dismounting 159, 161
- dual tires and their care 163
- full-circle retreading 196
- Goodyear airwheel 153
- inner tube repairs 170
- inspecting, repairing, and vulcanizing balloon tires 174
- mounting and dismounting 162, 167
- plies 148
- tire loads 155
- treads 152
- tubes 147
- types 153
- U.S. method of repairing low-pressure tires 183
- U.S. "Royal" tractor 154
- U.S. super-balloon 153
- valves and valve cores 159
- wheel alignment 158

Toe-in 29, 42, 52, 54
Transfer pump 377
Transmission brakes 299
Transmissions for trucks 427
Tread contour 188
Trouble shooting chart for brake service 220

Note.—For page numbers, see foot of pages.

Page

- Trouble shooting on Bendix duo-servo brakes 282
- Truck air cleaners 423
- Truck clutches 425
- Truck wheels 141
- **Trucks** 405–448
  - air cleaners 423
  - brakes 437
  - clutches 425
  - cooling system 418
  - lubrication system 415
  - mechanical details 405
  - rear axles 431
  - selecting a truck 445
  - transmissions 427
- Tubular axles 48

U

- U.S. method of repairing low pressure tires 183
- U.S. "Royal" tractor tire 154
- U.S. super-balloon tire 153

V

- Vacuum brake cylinder 215
- Vacuum system of air brakes 214
- Vacuum operated trailer coach brakes 240
- Vacuum power brake hookup 216
- Valve gears 392
- Valve springs 412
- Valves 411
- Valves and valve cores 159
- Variable-stroke pumps 341
- Viscosity 372
- Viscosity-gravity number 373
- Vulcanization 171

W

- Warner electric trailer brake 247
- Welded steel spoke wheels 139

Page

- Westinghouse spray valve 352
- Wheel alignment 158
- **Wheel brake units** 269
  - box type master cylinder 272
  - cast shoe 270
  - channel shoe 271
  - honing cylinders 272
  - hydraulic brake service and maintenance chart 275
  - repairs to master cylinder 271
  - repairs to wheel cylinders 272
  - shoe adjustment 273, 274
  - shoes 270, 271
- Wheel cylinders 270, 271
- Wheel support arm 36
- Wheel tramp and shimmy 32
- **Wheels** 133–145
  - balancing automobile 145
  - bus 141
  - cast-steel 142
  - passenger car 134
  - servicing 143
  - sizes 133
  - truck 141
- **Winton Diesel** 397
  - connecting rods and pins 404
  - cylinder heads 401
  - cylinder liners 398
  - frame 397
  - fuel-injection system 401
  - pistons 404
- Wire wheels 136
- Wood wheels 134
- Worm and gear steering gear 61
- Worm and nut gear steering gear 63
- Worm and roller type steering gear 65
- Worm and three-tooth sector steering gear 66

Note.—For page numbers, see foot of pages.

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